LIVERPOOL

GEOLOGICAL ASSOCIATION.

TRANSACTIONS.

VOLUME IV.

SESSION 1883-84.

Two Shillings and Sixpence.

LIVERPOOL:
PUBLISHED BY HENRY YOUNG, 12, SOUTH CASTLE STREET.

1884.

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INDEX.

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The Authors are alone responsible for the facts and opinions expressed in their Papers.

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ILLUSTRATIONS.

Erratum.

Page 35, line 7; read—"John S. Brodie, M.I.M.E."

LIVERPOOL

GEOLOGICAL ASSOCIATION.

ANNUAL REPORT,

1883.

LIVERPOOL GEOLOGICAL ASSOCIATION,

FREE LIBRARY, WILLIAM BROWN STREET, LIVERPOOL.

Council.

SESSION 1883–84.

PRESIDENT.

HENRY BRAMALL, M. INST., C.E.

VICE-PRESIDENT.

CHARLES E. MILES.

MEMBERS OF COUNCIL.

ISAAC E. GEORGE.

THOMAS BRENNAN.

H. T. MANNINGTON.

JOHN MORRIS.

DANIEL CLAGUE.

TREASURER.

WILLIAM H. WALKER,

Botanic View, Smithdown Lane, Liverpool.

SECRETARY.

OSMUND W. JEFFS,

8, Queen's Road, Rock Ferry, Birkenhead.

THIS COUNCIL WILL CONTINUE UNTIL OCTOBER, 1884.

LIVERPOOL GEOLOGICAL ASSOCIATION.

ANNUAL REPORT,

Session 1882-83.

1st October, 1883.

Your Council have again the pleasure of reporting upon the position and work of the Association.

Since the last Annual Meeting, 37 new members have been added to the register, and 4 resignations have been received. The number of members now on the roll is 127.

The work of the Association has been actively carried on during the Session. Eleven Evening Meetings have been held, at which the following Papers have been read and discussed :—

The President's Address, by Henry Bramall, M. Inst., C.E.

"Note on the Artificial Production of the Diamond," by Willem S. Logeman, M.R.C.P., Lit., Hum., Cand.

"Note on the stem of a recent tree-fern from Australia," by Frederick P. Marrat.

"Some observations on Ammonites," by Frederick P. Marrat.

"Some observations on the Darwinian Theory of Evolution of Species," by Hugh F. Hall, F.G.S.

"On the Contorted Bunter Sandstones of Wirral," by Isaac E. George,

"On the Mineral Resources of New Zealand," Part I— Coal and Iron; by Henry Bramall, M. Inst., C.E. President.

"The Drift Deposits of Cromer," by T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

"THE MINERAL RESOURCES OF NEW ZEALAND," Part II—Conclusion;—by Henry Bramall, M. Inst, C.E. President.

"THE SUB-MARINE FOREST AT LEASOWE," by W. H. Miles.

"THE ARCHÆAN ROCKS OF CHARNWOOD FOREST," by the Secretary.

"THE PREPARATION OF ROCKS FOR MICROSCOPICAL EXAMINATION," by Henry C. Beasley.

"MANGANESE ORES," by Herbert Fox.

The following Field Meetings have been held:—

1882.

21st Oct.—New Tunnel Works, Edge Hill.

Leader:—MR. T. S. KEYTE. Sections in the Pebble Beds and Keuper Sandstones.

1883.

14th May.—Monsal Dale and Bakewell.

Leader—DR. RICKETTS, F.G.S. Sections in Carboniferous Limestone, with Toadstone; Black Marble at Ashford Chert Quarries at Bakewell.

2nd June.—Leasowe.

Leader:—MR. T. MELLARD READE, F.G.S. Sub-marine Forest and other Post-glacial deposits.

29th June. (Evening)—Tranmere.

Leader:—Mr. W. H. MILES. Sections of Drift in Mersey Railway Works; also section near Borough Road.

7th July.—Frodsham.

Leader:—MR. C. E. MILES, Vice-President. Sections in Waterstones and Lower Keuper Building Stones &c.

13th July. (Evening)—The Dingle, Toxteth.

Leader:—MR. G. H. MORTON, F.G.S. Sections in Upper Bunter; with large "fault."

27th July. (Evening)—Eastham.

Sections in Pebble beds &c. Mr. Morton, F.G.S. gave an address on the Triassic Geology of the district.

3rd to 6th August—Excursion for three days to Shropshire.

Leader:—DR. RICKETTS, F.G.S. Much Wenlock, Wenlock Edge, Harley, Rushbury, Hope Bowdler, Cardington Hill, Soudley Quarries, Church Stretton and the Longmynd were visited. Sections in Longmynd Beds, Caradoc Sandstones, Llandovery Beds, Wenlock Shale and Wenlock Limestone.

25th August.—Grimshaw Delf.

Leader:—Mr. Henry Bramall. M. Inst. C.E., President. Sections in Gannister Beds, Millstone Grit and Lower Bunter.

8th September.—Speke.

Leader:—Mr. T. S. Keyte. Sections in Pebble Beds and Boulder Clay.

22nd September.—Visit to the Museum,

Where Mr. Frederick P. Marrat exhibited and described the Phillips' Collection of Minerals.

The Experiment of Evening Excursions has been successful, and these have been amongst the most enjoyable gatherings of the Session.

It affords the Council gratification to report that the results of their appeal in the last Annual Report, on behalf of the Library, have been so encouraging. In March, a catalogue of the books (bound volumes only) was prepared and the Library opened for the use of members. The thanks of the Association are due to—

Messrs A. W. Auden, *Henry Bramall, M. Inst., C.E. *A. H. Browne, D. Clague, T. R. Connell, *I. E. George, *T. S. Hunt, J. D. Howard, *T. Littlewood, *Geo. Lewis, Wm. Owen, *H. T. Mannington, W. Martin, F. P. Marrat, C. E. Miles, W. H. Miles, *John Morris, G. H. Morton, F.G.S. A. Ramsay, F.G.S. (*Editor of the "Scientific Roll*)," T. Mellard Reade, F.G.S., *J. M. Roberts, Hopkin Thomas, *W. H. Walker, W. Whitaker, B.A., *Mrs. H. P. Shilston, Miss L. Williams,—who have presented books to the Library, many of which are of very considerable value.

The Association exchanges Publications with the following Societies and Institutes.

Belfast Naturalists' Field Club;
Birmingham Free Library;
Chester Society of Natural Science;
Chester Free Library;
Edinburgh Geological Society;
Lancashire and Cheshire Entomological Society;
Liverpool Amateur Photographic Association;
,, Astronomical Society;
,, Engineering Society;
,, Free Library;
,, Geological Society;
,, Law Students Association;

* Subscribers to "Geological Record,"

Liverpool Literary and Philosophical Society;
,, Naturalists' Field Club;
,, Philomathic Society;
,, Science Students' Association;
London Geologists Association;
Manchester Geological Society;
Norwich Geological Society;
Royal Geological Society of Cornwall;
Smithsonian Institution, Washington, U.S.A.

An appendix to the Catalogue will be found on page 8 of this Report, and the Council trust that, by further additions, the Library — which has already proved beneficial to the members,—will steadily increase in usefulness.

The third volume of the "Transactions" is in course of publication, and will be found to contain numerous papers of interest. One of the most valuable of these—the President's Paper on "The Mineral Resources of New Zealand,"—has been re-printed by special request. The Council desire to convey the thanks of the members to those authors who have kindly undertaken the publication of their papers *in extenso* in the Transactions.

The Transactions are published subject to the conditions following:—

That every member reading a Paper is requested to furnish an Abstract of his Paper, not exceeding six pages of ordinary foolscap writing, which will be printed at the cost of the Association; but the Association will undertake to print any approved paper in full, on consideration that the author will pay at the rate of Two Shillings and Sixpence per printed page for all beyond the first four. The Association will also print illustrations to any paper at the cost of the author. Every author of a paper will receive twenty copies of the print of his paper.

The financial statement of the Treasurer, having been duly audited in accordance with the laws, is appended to this Report. After providing for all liabilities, there is a balance of cash in hand of £1 : 6 : 3.

In conformity with Law III, the officers of the Association will require to be elected at this meeting.

LIVERPOOL GEOLOGICAL ASSOCIATION, *In Account with the Treasurer.*

FOR THE YEAR ENDING SEPTEMBER, 1883.

Disbursements.

		£	s	d
1883				
Sept.	To Rent of Room and Attendant	3	5	0
,,	,, Printing and Stationery	38	9	9
,,	,, Postages and Incidentals	7	0	1
,,	,, Balance	1	6	3
		£50	1	1

Receipts.

		£	s	d	£	s	d	£	s	d
1882. Sept.	By balance brought forward..							1	11	6
1883. Sept.	,, Subscriptions, viz—									
	,, 127 Members, at 5s......				31	15	0			
	,, 2 Members paid in advance last year, at 5s	0	10	0						
	,, 18 Members in arrear, at 5s............	4	10	0						
	— 20				5	0	0			
	,, 107 Subscriptions, for the year 1882-83, at 5s.				26	15	0			
	,, 5 Ditto 1883-84, at 5s.				1	5	0			
								28	0	0
	,, Receipts from Members for Printing							19	8	3
	,, Receipts from Sale of Transactions							1	1	4
								£50	1	1
1883. Sept.	By Balance brought down							1	6	3

Audited and found correct,

THOS. R. CONNELL,
HOPKIN THOMAS, } Auditors.

Liverpool, 20th September, 1883.

W. H. WALKER,
TREASURER.

LIVERPOOL GEOLOGICAL ASSOCIATION.

LIBRARY REGULATIONS.

1—Books are issued to Members between 7.30 and 8 o'clock, on the evenings when Ordinary Meetings are held. (the first Monday in the Month.)

2—The time allowed for reading is ONE MONTH. This time may, however, be extended for a further period of ONE MONTH, provided that the book be not required by another reader, at the discretion of the Librarian.

3—Only one book will be allowed at a time to each borrower.

4—Borrowers must replace any Volume damaged whilst in their possession.

The Council reserve the right to discontinue the issue of Books whenever necessary.

BY ORDER OF THE COUNCIL. ANTHONY W. AUDEN, LIBRARIAN.

APPENDIX TO CATALOGUE OF BOOKS.

Issued March, 1883.

BOUND VOLUMES :—

53 Bibliographical Papers by *W. Whitaker, B.A. F.G.S.*
CONTENTS: Lists of Works on the Geology of Oxfordshire, Berkshire and Buckinghamshire, Wales, Cumberland, and Westmoreland, Cornwall, Cambridgeshire, Hertfordshire, and Hampshire.

54 Fossil Men. *Dawson.*

55 Geological Pamphlets, (Miscellaneous,) Vol. 1.
CONTENTS: T. Mellard Reade on Glacial deposits of the Clyde—Drift Deposits of Cromer—Chalk masses in Cromer Drift Cromer Forest Bed Section at Hightown—Drift Beds of N. W. of England (Part II) Rivers; G. H. Morton on Strata between Carboniferous Limestone and Coal Measures in Flintshire;—L. Fletcher on Meteorites; Brit. Mus Catalogue;—W. Whitaker on Subaerial Denudation and Cliffs and Escarpments—On Red Crag:—H. C. Marsh on Ancestral Man—Darwinism and Evolution;—British Association Addresses; Tertiary deposits of Hampshire and Essex (Etheridge)—Flora of Carboniferous Era (Williamson);—Reports on Erratic Blocks - Underground Waters—Cretaceous Polyzoa.

56 Henry, Joseph, Memoir of; *Smithsonian Miscell. Coll.*

57 Literary and Philosophical Society, Liverpool, *Proceedings*, 1881-1882.

58 Liverpool Geological Association, *Transactions*, Vol. III, 1882-83.

59 London, Guide to the Geology of; *W. Whitaker.*

60 New Zealand, Mineral Resources of; (with map) *H. Bramall, M. Inst. C.E.*

61 ———— Reports of Geological Survey, *Dr. Hector.* 1874-6; 1876-7.

62 ———— ———— 1877-8; 1879-80.

63 Old Red Sandstone. *Hugh Miller.*

64 Recent and Fossil Shells, Treatise on. *Woodward.*

65 Smithsonian Institution. "Reports," 1878.

66 ———— ———— 1879.

67 ———— ———— 1880.

68 Story of the Earth and Man. *Dawson.*

69 World before the Deluge. *Figuier.* Translated by Henry Bristow.

LAWS

OF THE

LIVERPOOL GEOLOGICAL ASSOCIATION,

Established 3rd June, 1880.

RULES PASSED 15TH NOVEMBER, 1880.

OBJECT.

The object of the LIVERPOOL GEOLOGICAL ASSOCIATION *is to promote the study of Geology and its allied Sciences.*

RULES.

I.

That every Candidate for membership shall be proposed and seconded by two members of the Association, and balloted for at the next Ordinary meeting; and the consent of three-fourths of the members then present shall be necessary for the admission of such Candidate.

The proposal shall be made on Form A, which must be filled up and lodged with the Secretary one week before the meeting at which the Candidate is to be proposed. The proposal form shall be submitted to the Council, and the Secretary shall report to the members any remarks the Council may deem it expedient to make thereon.

II.

Every member shall pay an annual subscription of Five Shillings, payable on the 1st October, or in the case of a new member, within one month after election. Any member not paying the subscription within three Calendar months, after being twice informed by the Secretary that it is due, shall no longer be considered a member of the Association.

III.

The Officers of the Association shall be a President, Vice-President, Treasurer, Secretary, and five other members, who together shall constitute the Council to manage and direct the affairs of the Association. Five to form a quorum. The officers shall be elected at the Annual Meeting, to be held in October; retiring officers shall be eligible for re-election. Any vacancy occurring during the year shall be filled up by the Council.

IV.

The Treasurer's Financial Statement shall be presented to the Association, with the Annual Report, after having been duly audited by two members proposed, seconded, and elected at the last meeting of the Session.

V.

The Ordinary Meetings shall be held on the first Monday in each month, at Eight o'clock in the evening. The order of proceeding at such meetings shall be :—

1.—The ordinary business of the Association.

2.—Miscellaneous Communications.

3.—Original Papers or Communications, to be followed by discussion thereon.

4.—Announcement of business for the next meeting.

VI.

A Special Meeting may be called at any time by the Council; and they shall be bound to call such a meeting on receipt of a requisition signed by not less than ten members, stating the purpose for which the meeting is to be convened. Seven days' notice of a Special Meeting shall be given to every member, such notice to specify the business to be considered, and the meeting shall be held within twenty-one days after the receipt of the requisition. No other business shall be considered at a Special Meeting except that for which it has been called.

VII.

Field Meetings shall be held at places of Geological interest, but none of the private business of the Association shall be transacted on such occasions.

VIII.

The votes on any question brought before the Association shall be taken by a show of hands, except those for the election of officers and new members, which shall be taken by ballot.

IX.

The Manuscript of every Paper read, or a clear and legible copy thereof, written on foolscap, shall become the property of the Association, and shall be placed in the Library for the use of the members.

X.

In case of non-compliance with the Rules of the Association, or misconduct by any member, such member may be requested by the Council to resign. Failing to do so, the Council may bring the case before a meeting of the Association which shall deal with it as may seem expedient.

XI.

Every member may introduce a friend at any Ordinary or Field Meeting of the Association, provided, however, that no person qualified to become a member be admitted as a Visitor more than twice in the same year.

XII.

No addition to, or change in these Rules shall be made, except by a majority of not less than two-thirds of the members present at a Special Meeting to be convened for that purpose.

LIVERPOOL GEOLOGICAL ASSOCIATION.

FORM A.

M ....

....

being desirous of admission to the Association, We, the undersigned, recommend h as a proper person to become a Member.

Dated....................18

Proposed by..

Seconded by... ....

Date Proposed ....

Date Elected ....

Signature of Candidate ....

....Secretary.

REGULATIONS FOR THE ADMISSION OF MEMBERS.

RULE 1—That every Candidate for membership shall be proposed and seconded by two members of the Association, and balloted for at the next ordinary meeting; and the consent of three-fourths of the members then present shall be necessary for the Admission of such Candidate.

The Proposal shall be made on Form A, which must be filled up and lodged with the Secretary one week before the meeting at which the Candidate is to be proposed. The proposal form shall be submitted to the Council, and the Secretary shall report to the members any remarks the Council may deem it expedient to make thereon.

RULE 2—Every Member shall pay an annual Subscription of Five Shillings payable on the 1st October, or, in the case of a new member, within one month after election. Any member not paying the subscription within three calendar months, after being twice informed by the Secretary that it is due, shall no longer be considered a member of the Association.

LIVERPOOL GEOLOGICAL ASSOCIATION,

LIST OF MEMBERS,

Session 1882-83.

Auden, Anthony W.	94, Jacob Street, Liverpool
Banister, H. C.	Rossett Road, Crosby
Barber, J. M.	4, Eyes St., Breckfield Road North Liverpool
Beasley, H. C.	Leam Cottage, Wavertree
Biram, Benj., Assoc. M. Inst., C.E.,	St. Helens, Lancashire
Biram, B. Swinton, B.A.. ..	Sherdley, St. Helens
Bramall, Henry, M. Inst. C.E. (President)	3, Balmoral Road, Elm Park, L'pool
Brennan, Thos., (Member of Council)	37, Towson Street, Liverpool
Broadfoot, Bruce M.	67, Huskisson Street, Liverpool
Broadhurst, Miss E.	Belmont Drive, Newsham Park, Liverpool
Broadhurst, Miss M. A.	6, Rokeby Terrace, Hillhead, Glasgow
Brodie, Alexander	202, Upper Parliament St., L'pool
Browne, A. H.	33, Hampden Street, Higher Tranmere, Cheshire
Brown, H. E.	25, Bank Road, Bootle
Cade, Lawrence W.	15, Upper Parliament Street, L'pool
Capon, R. M., L.D.S.	114, Vine Street, Liverpool
Carter, C. W.	4, Springfield, Everton, Liverpool
Clague, Daniel, (Member of Council)	81, Lime Grove, Lodge Lane, L'pool
Clarke, F. G.	47, Bickerton Street, Liverpool
Conlon, Bernard	22, Mount Pleasant, Liverpool
Connell, T. R.	Melville Chambers, Lord Street, Liverpool
Cooper, W. R., B.A.	11, Northumberland Terrace, Everton
Currie, Luke	3, Lord Street, Liverpool
Davies, David	Elsham House, Round Oak, Brierley Hill, Staffordshire
Davies, W. H. Junr.	55, Great Newton Street, Liverpool
Deuchar, P. B.	17, Kingsley Road, Liverpool
Duff, Samuel	55, St. Martins Cottage, Ashfield Street, Liverpool
Dunsford, A. J.	Wynch House, Seacombe, Cheshire

Edwards, George H.	2, Whitechapel, Liverpool
Elias, O. H.	Mere House, Mere Lane, Everton
Evans, J. C.	37, Ranelagh Street Liverpool
Findlow, John	42, Percy Street, Liverpool
Finlay, R. F.	Slater Court, Castle Street, L'pool
Fowler, Thomas Richard	139, Crown Street Liverpool
Fox, Herbert	11, Ash Grove, Seaforth
George, Isaac E., (Member of Council)	20, Cairns Street, Liverpool
Gould, Joseph	Cunard Road, Litherland, near Liverpool
Green, Charles H.	9, Lydia Ann Street, Liverpool
Grisewood. W.	Liscard Park, Liscard, Cheshire
Hall, Henry; H.M. Inspector of Mines,	Rainhill
Hall, Hugh F., F.G.S.	Greenheys, Grove Road Wallasey, Cheshire
Hedley, J. L., H.M. Inspector of Mines,	The Gables, Hooker's Brook, Chester
Henson, Samuel	227, Strand, London, W.C.
Hewitt, William, B.Sc.	21, Verulam Street, Liverpool
Hills, William	Fountain Street, Higher Tranmere, Cheshire
Houlding, William	34. Tynemouth Street, Liverpool
Howard, J. D.	109, Christian Street, Liverpool
Hunt, T. S.	9, Wordsworth Street, Liverpool
Jeffs, Osmund W.	8, Queen's Road, Rock Ferry
Johnson, T. M.	60, Lord Street, Liverpool
Jones, J. C.	82, Windsor Street, Liverpool
Jones, J. D.	72, Harrowby Street, Liverpool
Jones, R. E.	40, Arnold Street, Liverpool
Jones, R. T.	32, Canning Street. Liverpool
Jones, W. A.	32, Laurel Road, Edge Lane, L'pool
Jones, W. Joinson	7, Rhiwlas Street, Liverpool
Keyte, T. S.	9, Chatham Place, Liverpool
Kirkmann, H.	1, Egerton Place, Liscard, Cheshire
Kissack. J. M.	18, Queen's Road, Liverpool
Lawrenson, F. J.	131, Walton Village, Walton
Lewis, A. E.	Longton Villa, Rainhill
Lewis, George	81, Everton Terrace, Liverpool
Lister, R. F.	41, Deane Road, Liverpool
Littlewood, T.	40, High Street, Woolton
Logeman, Willem S., Lit. Hum. Cand., M.R.C.P.	Newton School, Rock Ferry, Cheshire

Maguire, T.	108, Landseer Road, Liverpool
Mannington, H. T., (*Member of Council*)	40, Rumney Road, Kirkdale, L'pool
Marrat, Frederick P.	21, Kinglake Street, Liverpool
Marrow, Fred.	20, Boundary Street, Liverpool
Martin, William	Station View, Yew Tree Rd. Walton
Miles, Charles E., (*Vice-President*)	57, Willow Bank Rd. Higher Tranmere, Cheshire
Miles, W. H.	3, Clifton Crescent, Birkenhead
Millard, Mrs. L. A.	2, Hope Terrace, Latimer Road, Forest Gate, Essex
Moore, C. Clifton, Junr.	125, Chester Rd, Hartford, Northwich
Moore, Miss Emily..	48, Eastbourne Street, Liverpool
Moore, T. J., C.M.Z.S.	The Museum, William Brown St. Liverpool
Morgan, C. H.	72, Bank Road, Bootle
Morgan, James	City Engineer's Office, Dale Street, Liverpool
Morris, John, (*Member of Council*)	40, Wellesley Road, Liverpool
Morris, Mrs. John..	40, Wellesley Road, Liverpool
Nicholls, John	11, Chatham Place, Liverpool
Owen, William	4, Comus Street, Liverpool
Owens, Philip	66, Orient Street, Liverpool
Padley, F.	15, Church Street, Liverpool
Paton, Rev. Wm., M.A.	Mossgiel House, New Ferry, Cheshire
Plastow, James	169, Great Homer Street. L'pool
Pratt, Miss E.	15, Alt Street Liverpool
Pritchard, D. D.	10, Lothair Road, Anfield
Quilliam, W. H.	49, Rufford Road, Liverpool
Reade, T. Mellard, C.E. F.G.S. .. F.R.I.B.A.	Park Corner, Blundellsands, Lancashire
Ricketts, Charles, M.D. F.G.S. ..	22, Argyle Street, Birkenhead
Roberts, Isaac, F.G.S.	Kennessee, Maghull
Roberts, J. Meredydd	20, Lowther Street, Liverpool
Roberts, Robert	9, Northumberland Terrace, L'pool
Robins, G. J.	Ashton Cross, Newton-le-Willows
Robson, George	66, Roscoe Street, Liverpool
Rogers, James E. A.	7, Oak Terrace, Beech Road, Fairfield, Liverpool
Ross. Alex. M. Inst. C.E. ..	L. & N. W. Ry., Edge Hill, L'pool
Rowett, Charles	2, Verulam Street, Liverpool
Rowlands T. V.	89, Duke Street, Liverpool

Rundell, T. W.	Litherland Park, Liverpool
Scott, George	131, Falkner Street, Liverpool
Sharpe, Granville H., F.C.S. ..	Batavia Buildings, Hackin's Hey, Liverpool
Shilston, Capt. H. P.	1, Saltoun Terrace, Seacombe
Shilston, Mrs H.P.	1, Saltoun Terrace, Seacombe
Shilston, Thomas, M.I.N.A. ..	31, Westmoreland Road, Newcastle-on-Tyne
Shilston, Mrs Thomas	31, Westmoreland Road, Newcastle-on-Tyne
Simpson L. C.	Falkland Road, Egremont, Cheshire
Smith, Edward	15, Upper Parliament Street. L'pool
Storey, John	27, Gibson Street, Liverpool
Tapscott, R. L.	41, Parkfield Road, Liverpool
Tate, A. Norman, F.I.C.	9, Hackins Hey, Liverpool
Tate, George, Ph.D. F.G.S. ..	College of Chemistry, 96, Duke, Street, Liverpool
Tate, John A.	43, Admiral Street, Liverpool
Thomas, Hopkin	4, Cable Street, Liverpool
Tildesley H. F.	121, Queen's Road, Liverpool
Walker, William H., (Hon. Treasnrer,)	Botanic View, Smithdown Lane, Liverpool
Ward, Thomas	Northwich, Cheshire
Westcott, H.	94, Prince's Road, Liverpool
Wigzell, Miss M.	22, Russian Drive, Tue Brook, Liverpool
Williams, J. J.	19, Falkner Street, Liverpool
Williams, J. M.	The Hawthorns, Hawthorn Road, Bootle
Williams Miss L.	Hill Top, Bradfield, near Sheffield
Williams, T. G.	Moss Bank, Croxteth Road, L'pool
Williams, T. H.	2, Chapel Walks, Liverpool
Wright, W...	41, Langham Street, Walton
Young, Henry	12. South Castle Street, Liverpool

Proposed for Election, 1st October, 1883.

Downie, George	19, Oakfield Street, Liverpool
James, Raoul	309, Upper Parliament St. L'pool
Potter, Charles	101, Miles Street, Liverpool
Rowe, Edmund	23, Frodsham Street, Tranmere, Cheshire

Abstract of Proceedings

OF THE

LIVERPOOL GEOLOGICAL ASSOCIATION.

SESSION 1883-84.

1st October, 1883.

The Annual Meeting was held this date, at the Free Library, MR. HENRY BRAMALL, M. Inst., C.E., President, in the Chair.

The following were elected Members:—Messrs. Edmund Rowe; George Downie; Charles Potter; and Raoul James.

Proposed as Members:—Messrs. Robert A. Sharpe, 5, Welbeck Terrace, Birkdale, Southport; John R. Webb, 29, Fountain Street, Higher Tranmere; John G. Evans, Brunswick Dock, and Mrs. Robson, 17, Nile Street, Liverpool.

DONATIONS.

Lists of Works on the Geology of Oxfordshire, Berkshire and Buckinghamshire; of Cumberland and Westmoreland, by William Whitaker, B.A., F.G.S.—*presented by the Author*;—British Association Reports; On the Fossil Polyzoa, On Underground Waters; Address to Geological Section on Plant Life of the Carboniferous Epoch, by Prof. W. C. Williamson, F.G.S.—*presented by Mr. William Whitaker, B.A. F.G.S.*,—Geological Survey Memoir of Prescot, (2nd Edition); Cheltenham; Abstracts of Papers read before the North of England Institute of Mining and Mechanical Engineers—On the duration of Coal in Gt. Britain and Ireland; On the Feeding and Management of Colliery Horses; On the Channel Tunnel: On Boiler Explosions; On the Hœmatite deposits of Furness; Charter and New-Bye-Laws of the Institute;—Reports of the Geological Exploration of New Zealand. 1874-76; 1876-7; 1877-8; 1879-80,—*presented by Mr. Henry Bramall, M. Inst. C.E., President,*

The Annual Report and Treasurer's Statement of Accounts were then presented to the Meeting, and the officers for the Session 1883-4, as named on page 2 of the "Report," were elected.

COMMUNICATION.

Mr. Edward Charlesworth, F.G.S., of London, gave some interesting Notes on the Fossils found in the Red Crag of Suffolk.

This was followed by an

ADDRESS BY THE PRESIDENT,

who, after referring to the satisfactory state of the Association, and the progress made, as disclosed by the Report just read, pointed out that, as in former Sessions, each of the various branches of Geological Science had been brought under the notice of the members. In Petrology, attention had been directed to the Contortions in the Bunter Sandstones of this district by Mr. George, to the Drift deposits of Cromer and the beds at Leasowe by Messrs. Reade and W. H. Miles, and to the very interesting igneous rocks of Charnwood by Mr. Jeffs. In Chemical Geology an excellent paper was contributed by Mr. Logeman detailing a series of experiments on the Synthetical production of the Diamond; and the President's papers on the Mineral Resources of New Zealand, Mr. Fox's paper on Manganese Ores, and the visit paid to the Phillip's Collection of Minerals under Mr. Marrat's guidance, evidence the interest taken in Mineralogy. Our City may be congratulated on possessing the Phillip's Collection, which is unique, and has an interest quite its own, from being the original one on which the father of British Mineralogy founded his classical "Introduction," the figures and descriptions of which have been copied into successive text books, and generally without acknowledgment. The Curators of the Museum have very wisely arranged the specimens as much as possible in accordance with the gifted author's own work as last revised by him.* See-

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* *Elementary* Introduction to Mineralogy, 3rd Edition, published 1823.

ing how much the use of the Microscope for the determination of Rock species is extending, the practical paper by Mr. Beasley on the preparation of Rocks for Microscopical Examination was most opportune, and its value was further enhanced by the examples in the various stages of manipulation by which it was accompanied.

Palæontology received attention from Mr. Marrat, who read a paper on Ammonites; and Mr. Hall, who, in his paper on the Darwinian Theory of Evolution, pointed out the difficulties he had in accepting that theory. This paper gave rise to the most spirited and interesting discussion of the Session, without, however, eliciting any satisfactory explanation of the difficulties raised. The President mentioned that some of the most eminent scientists are now earnestly considering this matter, and referred more especially to Prof. Dawson's Address to the American Association for the Advancement of Science (printed in *Nature* of 6 Sept. last), and Prof. Williamson's Address to the Geological Section of the British Association at Southport (reported in *Nature* of 22nd Sept.), as indicating the current of thought among those best able to form clear and unbiassed judgments. These gentlemen point out that there are long lines of descent in Ferns and Club mosses, without development, that in fact the Ferns, Conifers, and Lycopods of the Palæozoic Rocks have no known ancestry, and are themselves of no lower type than their modern descendants; that the rocks afford no evidence of the introduction of animal life in embryonic forms, but that such life on its first appearance is often in forms highly perfect and specialised; the Trilobites of the Cambrian for instance are many-segmented and complex, and the Batrachians of Carboniferous, and Reptilia of Permian Age are as fully developed and of as high a type as their modern successors. The hypothesis that the so-called "struggle for existence" can give rise to new forms of life is a fallacy, a mere figment of the imagination, unsupported by a single fact. Another difficulty is the sudden appearance of forms of life in great abundance, in widely separated localities; in the Cambrians,

we are *suddenly* confronted with an almost complete invertebrate fauna. One of the Professors in a local College, recently in a public speech, after statlng that Scientists are now practically of one mind in accepting evolution (a statement a little loose, though, of course applauded by the unthinking multitude,) went on to say, "the main object and end of all biological investigation is admittedly to establish this great theory, on, if possible, a still firmer foundation than it has." Let us hope that this narrow view of the object and aim of scientists is peculiar to the gentleman who ventured to enunciate it; at all events, let *our* "main object and end" as Geologists be to try patiently to get at facts, and to seek out the Truth, and by that test alone try this Evolution, as well as every other theory. Let theory be judged of by facts, and not facts be twisted to support theory, and the theory which will not stand this test, let sink into merited oblivion. Possibly if we could free ourselves from the seductive glamour of evolving worlds out of our own inner consciousness, we might be able to get a little nearer to truth. The papers by Professors Dawson and Williamson are written in the true spirit of earnest seekers after truth, and are well deserving of careful and thoughtful study by every member of this Association.

Much good practical work has been accomplished during the past Session in the Field Meetings, which took place at Leasowe, Tranmere, and Speke for the examination of Recent and Drift deposits; at Edge Hill Tunnel, Tranmere, Eastham, Speke, the Dingle, Frodsham, and Grimshaw Delf, for the working out of the various members of the Trias, and at Grimshaw Delf, where were seen sections of Ganister Beds and Millstone Grit. At Monsall Dale and Bakewell besides the Carboniferous Limestone, opportunity was afforded to study the effects of igneous intrusion, while three days in August were very pleasantly and profitably occupied in tracing out the Silurians of Wenlock and the Longmynd, and the cabinets of some of the members were enriched by many choice fossils there collected. No visits have yet been paid by the

Association to the Permian, nor the Cambrian and Archæan rocks, and it is desirable that this should be done during the coming Session; and if another two or three days' excursion can be arranged. the Tertiary, Cretaceous, or Jurassic formations claim attention, as we have no such deposits accessible within the compass of a single day. The evening field meetings held last summer were so successful that they should be continued more especially for the study of those features which are to be observed quite close to hand.

The appeal of the Council for books to form a lending Library, was responded to by many of the Members in the most generous manner, and the result you may see in the shelves of our bookcase which contain already quite a respectable number of standard works, including some of the most recent contributions to the science. That there existed a pressing need for such a library is shewn by the avidity with which the books have been borrowed and read, and it is hoped most earnestly that the zeal of our members may not slacken, that those who have not yet contributed to the Library will endeavour to do so to the best of their ability, and that, by hearty co-operation, we may make this important feature worthy of our Association, and a powerful means towards the attainment of the end we have in view, — the very raison d'être of our existence as an Association, viz. :—

"*To promote the study of Geology and its allied Sciences.*"

OPEN MEETING.

The following were some of the principal objects and specimens exhibited ;—

Series of fossils from the Red Crag of Suffolk, by Mr. E. Charlesworth, F.G.S.—Silurian Fossils, by Dr. C. Ricketts, F.G.S.—Wenlock Fossils, by Mr. Barber and Mr. Robson.—Minerals and Photographs, by Mr. T. S. Hunt;—Silver Ores

from Nevada, Mr. Henry Bramall, M. Inst., C.E. (President) Rock Specimens and Photographs from Pembrokeshire, Mr. I. E. George;—Felspar Minerals, Mr. C. E. Miles;—Copper Ores, Mr. T. Brennan;—Dolomite Minerals, Mr. H. T. Mannington;—Quartz Specimens, &c., Mr. D. D. Pritchard;—Geological Album of Fossils, Mr. D. Clague;—Microscopes, Messrs. D. Clague, H. C. Beasley and Willem S. Logeman—Series of water-colour drawings of Shropshire, and microscopic slides illustrating the process of mounting rock sections, by H. C. Beasley;—Geologists' Field Implements, Mr. S. Henson (of London);—set of Water-testing and Blow-pipe apparatus, Mr. W. Ambrose Taylor, (of Penzance,) &c., &c.

LIVERPOOL GEOLOGICAL ASSOCIATION.

November 5th, 1883.

At the Ordinary Meeting, held this date at the Free Library, Mr. Henry Bramall, M. Inst., C.E., President, in the Chair, the following were elected as Members:—

Messrs. Robert Sharpe, J. H. Webb, J. G. Evans, and Mrs. Robson.

Proposed as Members:—

Messrs. R. McMillan, 34, Salisbury Street; Peter H. Marrow, 28, Humber Street; Edward Evans, 35, Beresford Road, Toxteth Park; John Fraser, 1, Railway Cottages, Spekeland Road; and Laurence Small, 1, Rutland Street, Everton, Liverpool.

DONATIONS.

"Chemical Denudation in Relation to Geological Time," by T. Mellard Reade, F.G.S.,—*presented by the Author*; "The Universe," by E. Pauchet —*presented by Mr. C. Rowett*; "Proceedings" No. 2, Vol. 8, and Index to Vol. 7, Geologists' Association of London; "Proceedings," Sept. 1883, Liverpool Astronomical Society,—*presented by the respective Societies*; "Announcement, for year 1883," Wagner Free Institute of Science, Philadelphia,—*presented by the Principal.*

The following Paper was read—

"ON THE DENUDATION OF LIMESTONE,"

By Isaac E. George.

Of the endless variety of rocks in Britain, there are few which will better repay examination by the traveller in search of the picturesque, or geological student anxious to gain some idea of the process of change going on in the Earth's crust, than its Limestones. And this is especially true of the great marine series forming the base of the Carboniferous System. The great Limestone plain of Ireland, the bold headlands of the Irish Sea, and the mountain mass of the Pennines, all are productive of scenes as fascinating to the eye as they are

bewildering to the imagination, when it is attempted to grapple with the numerous problems suggested by their appearance. But before seeking to explain the nature of the changes through which our Limestone rocks are now passing, it is necessary that some introductory remarks should be made about their chemical composition, structure, and origin

Carbonate of Lime is the substance of which Limestone is composed, and to this is usually added a slight percentage of clay. In the great Limestone masses of which I now treat the Carbonate of Lime is found to take the form of the hard parts of animals; and this is no accidental resemblance. It was one of the first established principles of geological science that Limestone originated on the floors of the ocean by the gradual accumulation of the calcareous skeletons of animals which had once enjoyed life in the waters. This explains why it is that Limestones furnish us with more fossils than any other rock. It is also a part of the economy of nature that the ocean bottom should frequently be upheaved, laid dry, and elevated into continental masses of land. If the elevation be accompanied by disturbance, or if it be effected unequally in adjacent areas, the rocks will be tilted up at various angles to the horizon. In other words they will have a *dip*. Where the rock is exposed in a section, as in a quarry or cliff, something may be learnt as to its physical structure. There are always present a series of more or less horizontal lines dividing the Limestone into distinct sheets, or *strata*. These are the stratification planes, and they indicate variations in the mineral composition, and pauses during the accumulation of the rock. At right angles to these are other lines, fine cracks dividing the strata into blocks, known as *joints*. Shrinkage during the setting or consolidation of the once pasty limestone produced these.

Speaking generally, the disintegration of rocks is effected by three kinds of forces, the Mechanical, Chemical, and Organic. In the case of Limestone a greater part of the work is brought about by chemical agencies, especially where, as in *our own country*, there is a copious rainfall, and abundance

of decaying vegetable matter. These two conditions are necessary before the Limestone can suffer loss from chemical solution. Decaying plants are found to give off large quantities of Carbonic acid gas (*Carbon dioxide*), and rainwater passing over vegetable mould dissolves the gas, and so gains the power of attacking calcareous rocks. (A valuable paper recently laid before the Association by Mr. Norman Tate,* enters more fully into this part of the subject.) When the acid waters are brought into contact with a limestone surface, portions of the rock are immediately dissolved, and the resulting *bicarbonate of Lime* perhaps hurried away to the sea at once. In this way the surface rapidly becomes honeycombed and fretted with small channels and depressions. But it is not the superficial rock alone which suffers from the attacks of acid water. The *joints* are utilised for its passage underground and from being mere cracks in the rock they are gradually widened until, if the process be sufficiently long-continued, they result in a series of yawning fissures, and, futhermore, as the upper portions of the *joints* are the earliest reached by the acid rainwater, so they are first to rob it of its contained gas, the result being that more Limestone is dissolved there than is the case at a greater depth. In this way the peculiar *swallow-holes* of Limestone tracts have been developed. These are funnel-shaped openings which conduct underground not only the water drainage from their immediate neighbourhood, but very often small streams and rivers. Most of these features can be observed in districts occupied by the Carboniferous Limestone Formation, though the Central Plain of Ireland by its great extent, and the Derbyshire and Craven districts by reason of their superior elevation, shew them under specially favorable circumstances. Limestone 'pavements' are well developed in all these districts. A rock surface bare of soil has its *joints* widened to such an extent by rainwater that the Limestone shews a series of tabular blocks, separated from each other by deep trenches. The water which has found its

Vide "Chemical Action in relation to Geological change," by A. Norman Tate, F.I.C.—*Transactions*, Liverpool Geol. Assoc., Vol. ii. p. 23.

way down through these openings may continue its underground circulation for many miles, stream joining stream until large rivers are formed. The long dark tunnels and galleries forming the channels of such subterranean streams as the Wye near Buxton, were not always so extensive as they now are. Narrow cracks have been widened by constant circulation of water against their sides, and larger and larger bodies of water admitted with increasing width, until they have attained the dimensions and appearance so familiar to Derbyshire tourists. Such watercourses display those abrupt turnings and profound cascades which might be looked for where the drainage has always been conducted along *stratification planes* and *joints*. In the Craven district (north-west corner of Yorkshire), the formation of swallow-holes and underground watercourses is powerfully influenced by mechanical agencies. Here the Carboniferous Limestone supports outliers of Millstone Grit and Yoredale rocks, so that streams coming down Ingleborough and other neighbouring mountains bring with them large quantities of pebbles and sand, which are engulphed directly the limestone 'pavements' are reached. No wonder then that large potholes are found in connection with the underground waterfalls of Craven.

In those districts which furnish the most striking instances of subterranean wear and tear the Limestone is placed at a high elevation, and frequently has a rapid slope; but where an extensive tract of Limestone is found at a low level and comparatively horizontal, as in the Central Plain of Ireland, some effects are produced which are not observable in Great Britain. There the flatness of the country causes its rivers to be unusually sluggish, so that they have abundant time to dissolve away their Limestone banks. Hence result the chains of vast lakes occupying the basins of the Shannon and Erne, features quite unique in the Physical Geology of the whole world. Professor Hull, in his "Physical Geology and Geography of Ireland" (p. 201), forcibly remarks that "these lakes are, strictly speaking, irregular hollows dissolved out of the Lime*stone floor, and* filled with water. Their sides are often most

irregular in form, and when laid down on a map strongly suggest the idea of encroachment on the shores by a process of melting." The same principle applies to the large bays fringing certain parts of the Irish Coast, as "where the bays are most deeply indented, there the Limestone prevails", the margins and headlands being formed of older non-calcareous rocks. When to the conditions already named there is added that of a very moist climate it will be seen that denudation of Limestone in Ireland must be proceeding on a very extensive scale.

The escarpments marking outcrops of successive strata in a Limestone region are usually steplike and peculiarly characteristic. This feature is most marked in Anglesey, where the hard Carboniferous Limestone is inclined at a slight angle to the horizon, giving rise by atmospheric weathering to a series of abrupt steps, which follow each other in rapid succession. The great, rounded hills of Derbyshire, which offer apparent exceptions to this rule, have had their outlines powerfully modified by glacial action. The mechanical and chemical action of rivers, operating through many successive periods, is well illustrated in the grand series of dales which furrow the Carboniferous Limestone of Derbyshire; but the structure of these valleys calls for no special remark, as the features are much the same where the neighbouring Millstone Grit and Yoredale rocks are cut through. Probably they were first fashioned in these Upper Carboniferous rocks when the Limestone had not yet been exposed at the surface; so that the suggestion of their having originated from lines of caverns, the roofs of which have tumbled in, seems rather exaggerated and uncalled for. The destructive effect of the movements of ice-sheets over a Limestone surface may be favorably seen close to the cliffs on the South coast of Pembrokeshire. At St. Govan's, a series of strata rising to the surface at a slight angle have been planed down to a pretty uniform level; whereas, had they not been travelled over by ice, a number of scarped outcrops would be shewn. The Limestone strikes E. to W., the outcrop facing North.

A careful study of the operations carried on at the present day where Limestone 'pavements' and underground water-courses are accessible to observation, will render clear the meaning of certain natural features found in spots where the forces are not now acting with the same intensity, or under quite the same conditions. Thus it happens that marine denudation acting on the Pembrokeshire Limestone has often exposed, during the backward march of the sea-cliff, a number of large caverns and tunnels which need to be carefully distinguished from those caves, tapering gradually inwards, which the sea has power to excavate. Atmospheric denudation acting in the same locality has frequently uncovered the roofs of other caverns and fissures, producing the open chasms and curious circular hollows which ornament the Limestone heights above the sea-cliffs. The chasms are situated at spots where the Limestone is well jointed, the cracks being of great depth and very closely set, so that the rock is broken into a series of deep but very narrow blocks. Acid waters permeating through such joints would be capable of producing all the phenomena observable. Such open fissures have been exposed by denudation in all ages, and it is here that we are presented with one of the most interesting chapters in the history of Limestones. Lava streams flowing over such treacherous surfaces are likely to make but slow progress, and may give rise to some puzzling appearances in subsequent ages, when denudation shall have removed all the Lava excepting such as is to be found buried in the fissures. Mr. A. Quilliam, in a paper read before our Association* has drawn attention to one such instance in the N. of Ireland, where a fissure in the Chalk has been filled with a plug of Lava from above. Circular hollows and deep funnels are of common occurrence in the English Chalk. They are sometimes filled up with a clay, representing the insoluble part of large masses of Chalk which have been denuded, or they may be occupied by some of the sandy Eocene rocks often found resting on the

* Vide "The Giants' Causeway", by A. Quilliam. *Transactions, Liverpool Geological Association*, Vol. I. p. 10.

Chalk. These tend to fill up the Chalk funnels as quickly as they are developed by the solvent action of percolating waters. After the close of the Triassic period a number of open fissures seem to have existed in the Carboniferous Limestone of what are now the Mendip Hills, and during a subsidence of the land which placed them on the shores of the Rhœtic sea they formed receptacles for animal remains and sediment belonging to that period. But the chief interest of Limestone fissures arises from the fact that they often serve as sepulchres for the bones and teeth of land animals. Many caverns have been found filled with such remains, washed into them by streams during various periods from the Miocene upwards, the animal having died conveniently near to the swallow-holes on the surface. On the other hand there are numerous instances of open fissures into which living animals must have stumbled in great numbers. Windy Knoll fissure, near Castleton, is one of the best known instances. Its history has been told in a very graphic manner by Mr. Rooke Pennington, in his "Notes on the Barrows and Bone Caves of Derbyshire," page 76. The fissure has yielded an immense quantity of bones belonging to the Grizzly Bear, Bison, and Reindeer, many of the skeletons being complete. Elden Hole, an immense open fissure, 160 feet in depth, is in the same neighbourhood, and still awaits exploration.

Many caverns have, since their formation, been partly filled up with metallic ores, or with pendent stalactites and massive stalagmitic floors. The torrents which once coursed through them have found fresh channels, or are no longer in existence. Tiny droplets have taken the place of streams. But their glory is not yet departed. In the very decay of these tunnels there is life; for the slowly-growing stalagmites have covered up and preserved from decay some of the earliest known works of our species. Under such crystalline floors have been found the materials which tell us almost all we know of a remote time when our ancestors used rude weapons of flint and bone, and occasionally sought the friendly shelter of limestone caverns.

LIVERPOOL GEOLOGICAL ASSOCIATION.

December 3rd, 1883.

At the Ordinary Meeting, held this date at the Free Library, Mr. Charles E. Miles, Vice-President, in the Chair, the following were elected as Members—

Messrs. John Fraser, Edward Evans, Peter H. Marrow, and R. McMillan.

Proposed as Members—

Messrs. William Narramore, 5, Geneva Road, Elm Park; John S. Brodie, M. Inst., C.E., City Engineer's Office, Dale Street; and F. W. Ashton, 26, Woodville Terrace Liverpool.

DONATIONS.

"Wonders of Geology," by Mantell, 2 vols, (1848); "Geological Excursions," ditto, *presented by Mr. T. R. Connell*: "A Traverse of the Yorkshire Drift," by T. Mellard Reade, F.G.S., *presented by the Author*; "Proceedings," Vol. I, Parts 3 and 7, of the Norwich Geological Society; "Proceedings," Nov., 1883, Liverpool Astronomical Society, *from the respective Societies.*

Abstract of a Paper read on—

"METHODS OF STUDY IN CHEMICAL GEOLOGY."

By A. Norman Tate, F.I.C.

Notwithstanding that the study of chemistry in relation to geology has of late years received much more attention than formerly, it seems to me that chemical changes, and the chemical characters of rock-constituents are still not sufficiently considered in detail when probable modes of rock-forma-

tion, and other items of geological study are discussed. Certainly chemical details, in most of our geological text-books and monographs are too often almost entirely ignored or very insufficiently alluded to. I therefore submit that a more thorough and systematic study of chemistry by geologists would greatly assist in solving problems of great interest and importance. What is, I think, required is more systematic study of the reactions of rock constituents on each other under different circumstances. Probably an example will show my meaning clearer. In examining the limestone of a certain Welsh quarry, I found considerable difference in the chemical composition of examples taken from different points in close contiguity to each other, the variation being chiefly in the proportion of carbonate of lime and magnesia. In several cases the carbonate of lime was present to the extent of from 94 to 97 per cent. with carbonate of magnesia from 8 to less than 1 per cent., whilst many other samples gave from 30 to over 40 per cent. of carbonate of magnesia, and a corresponding decrease in the proportion of carbonate of lime. Other constituents of the stone, alumina, silica, oxide of iron and manganese, although present in small proportion, gave variations worth notice. In the immediate neighbourhood of the quarry, there is also an immense bed of tufa containing, in the dried state, nearly 98 per cent. of carbonate of lime. The problem of the formation of these limestones is an interesting one, but cannot be properly discussed without attention to several chemical facts. Most of the samples which yielded the largest proportion of carbonate of lime had the appearance of limestones built up to a great extent of organic remains, but in others, such indications were not so marked, and the samples containing most magnesia varied greatly in their general structure. We are here face to face with questions such as the following :—How far have these limestones been formed from the *debris* of animals? Are they to any extent the result of the deposition of sediment produced by chemical decomposition of salts present in solution in water? Have beds of organic remains become changed by *chemical action*, due to infiltration, with deposition of new

matters in the older beds, and removal of others to be carried further with deposition on a new site, or with further chemical change in their passage by meeting other matters to react upon and produce deposits of another character? Amongst other chemical reactions that should be considered in answering such questions are the decomposition of felspars with formations of alkaline carbonates; reaction of these carbonates on the chlorides of calcium and magnesium such as exists in sea water, with production of carbonates of lime and magnesia, and alkaline chlorides; the reactions of bi-carbonate of lime, or sulphate of magnesia; and of bi-carbonate of magnesia on chloride of calcium; solution of carbonates of lime and magnesia in water containing carbonic acid and deposition of these carbonates by evaporation of the carbonic acid and water. The character of the deposits under these different circumstances should be most carefully noted. Other chemical reactions and how they take place under different conditions should also be considered, but to do this, a fairly systematic knowledge of the chemical details is necessary. And here let me add that frequent, systematic, and detailed examinations of rock specimens by the microscope will also aid, but such examinations are far too seldom resorted to.* Methods of chemical examination of limestones are not particularly difficult, and simple modes of qualitative and quantitative testing of these and other geological specimens, that can readily be performed by those who are not great adepts in chemical manipulation, may often be employed. But the examinations should be systematic and not performed by mere random experiments with acid and alkalies and hap-hazard blow-pipe tests. Students of geology should always have some careful instruction in practical chemical details, and teachers of geology should see to this.

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*Mr. H. C. Beasley has kindly undertaken the microscopical examination of the limestone specimens alluded to, and has already forwarded to me interesting information. A.N.T.

In illustration of his remarks, the author showed many experiments, and several pieces of apparatus suitable for conducting easy processes for the examination of minerals and rock specimens were exhibited.

During the discussion on the above Paper, it was suggested that meetings should be held for the practical study of chemical and other tests used in the determination of rocks and minerals. In accordance therewith, the Council arranged for a short Practical Course, conducted by Mr. A. Norman Tate, F.I.C., to be held during February and March.

December 8th, 1883.

VISIT TO THE MUSEUM.

The First of a Winter Series of Visits to the Liverpool Public Museum, William Brown Street, was held this date.

The members met in the "Stone Gallery," where Mr. Frederick P. Marrat gave an Explanation of the cases illustrative of the Fossils of the Tertiary Epoch.

The proceedings at these Visits to the Museum are as informal as possible, and, so far as practicable, assistance is afforded to those desirous of studying the subjects selected for illustration.

LIVERPOOL GEOLOGICAL ASSOCIATION.

January 7th, 1884.

At the Ordinary Meeting, held this date at the Free Library, Mr. Henry Bramall, M. Inst. C.E., President, in the Chair, the following were elected as members:—

Messrs. Laurence Small, William Narramore, John S. Brodie, M. Inst., C.E., and F. W. Ashton.

Proposed as members:—

Messrs. John Hancox, 101, Prescot Street; J. W. Baylis, 56, Vine Street, Liverpool; and G. Watson Gray, 12, Argyle Street, Garston.

DONATIONS.

"Proceedings," Liverpool Philomathic Society, Vol. 28, for 1882-83, —Ditto Liverpool Geological Society, Part v. Vol. 4,—Ditto, London Geological Association, No. iii, Vol. 8,—Ditto, Mining Institute of Cornwall, No. 1 to 3 and 5 to 8;—"Transactions" Manchester Geological Society, Part xi. Vol. 17;—Ditto, Royal Geological Society of Cornwall, part v. Vol. 10,—*from the respective Societies*;—Papers on "The Post Tertiary and the Recent Geology of Cornwall" by W. A. E. Ussher, F.G.S., *presented by the Royal Geological Society of Cornwall*;—"On the Human Skull found near Southport," by T. Mellard Reade, F.G.S., *presented by the Author*;—"Report of Local Scientific Societies' Committee" (British Association,) by H. G. Fordham, *presented by the Secretary of the Committee.*

A Paper was read on

"THE BOULDER CLAY OF CHESHIRE, &c., AND THE ERRATICS CONTAINED IN IT."

By Charles Ricketts, M.D., F.G.S.

VISIT TO THE MUSEUM.

January 12th, 1884.

The SECOND of the Winter Series of Visits to the Liverpool Public Museum, William Brown Street, was held this date, in the " Stone Gallery" of the Museum, when an Address was given by Mr. T. J. MOORE, Cor. Mem. Z.S. Lond., (Curator of the Museum,) on—

" Illustrations of Fossil Ruminant Mammalia, from the Sivalik Hills of North West India; and Dr. Murie's views as to the relationship of *Sivatherium* to recent forms."

The Address was illustrated by Models and Specimens.

4th February, 1884.

At the Ordinary Meeting, held this date, at the Free Library, MR. HENRY BRAMALL, M. Inst., C.E., President, in the Chair, the following were elected Members :—

Messrs. John Hancox, J. W. Baylis, and George Watson Gray.

Proposed as Members :—

Messrs. J. M. Labouchere, 106, Spencer Street, and Peter H. Walsh, F.C.S., Lond., 41, Russell Street, Liverpool.

DONATIONS.

" Transactions," Liverpool Engineering Society, Vols I and III; Ditto, Manchester Geological Society, Part 12, Vol. xvi. ; " Proceedings," Liverpool Astronomical Society, Dec., 1883,—*from the respective Societies.*

The following Paper was read on—

"THE SUBSIDENCES IN THE SALT DISTRICTS OF CHESHIRE, AND THEIR GEOLOGICAL CAUSE."

BY THOMAS WARD.

The subsidences in the salt districts of Cheshire have, of late years, been brought very prominently before the public, owing to their rapid extension and the great destruction of property caused by them. Their connection with the manufacture of salt has also been clearly demonstrated. The intention of this paper is to treat them as purely geological phenomena, that is, modifications of the crust of the earth by well-known physical causes. They will be shown to be *denudations of rock-surfaces by water*. We have *sub-aërial* denudation; we have also *sub-aqueous*; but these subsidences are instances of *subterranean* denudation of a similar nature to the wasting of chalk rock by water, but on a more extensive scale. Nowhere on the surface of the earth can subterranean denudation be seen to greater advantage than in the salt districts of Cheshire. These subsidences are instances also, of lake formation on a considerable scale. Again, the destruction of the rock surfaces tends to produce a *fac-simile* of the country as it existed during the time of the formation of the beds of rock-salt. These phenomena are deserving of more study than geologists have given them, as they give a good insight into the geology of Triassic times, and if the salt beds were only carefully studied, the nature of the seasons in respect to dryness or humidity, could be clearly demonstrated.

The salt districts of Cheshire form a portion of the Great Red Marl area. The Keuper Marls in Cheshire occupy a basin of an elongated form, its greatest length being from north to south. As it is not necessary for the purposes of this paper to accurately point out the boundaries of this basin, I merely state here that the beds of salt which occur in Cheshire exclusively in the Keuper Marls, are not coextensive

with them, as has been frequently asserted, but occupy small isolated portions, The reasons why this should be so I will explain when touching upon the formation of the salt beds. The great salt districts of Cheshire are in the neighbourhood of Winsford and Northwich, the great centres of subsidence, whilst minor districts lie in the neighbourhood of Middlewich, Nantwich, and Wheelock near Sandbach, but in none of these districts has subsidence occurred—or only to such a limited extent as to scarcely attract notice.

The Cheshire rock salt formation belongs to the Triassic Period, and is almost, if not quite, confined to its latest member, the Keuper marls. Rock salt is found in many formations, commencing immediately after the Metamorphic rocks, but in this country at least, and to a great extent on the continent of Europe, it is most largely developed in the Triassic Period. To such an extent is this so that the period has been called the Age of Salt. Salt beds are being formed now, and at most periods of the earth's history the circumstances favourable to their formation must have existed in one place or another. No rock salt, however, can be expected to be met with in a purely deep sea formation, as salt cannot form unless the water is saturated—that is, contains about 26 per cent. of salt.

I will briefly describe the method of deposition of the Cheshire salt beds. I should prefer not to use the word "deposition," as it is liable to cause misapprehension. Salt is not a deposit, though the clay mixed with it is. The salt is held in solution, and, as the water evaporates, it *crystallizes* out. A true salt deposit can be made chemically, by mixing with the salt solution a chemical constituent, for which the water has a greater affinity than for the salt. In this case, the water lets go the salt which falls to the bottom as a fine white powder differing entirely from a rock salt formation. The beds of rock salt in Cheshire have been formed in a large salt lake, coextensive with the area of the Keuper Marls. Most probably—if not certainly, this lake was a portion of the sea shut off by the rising of the land, and the

formation of a bar or barrier across the mouth of a large bay. Be this as it may—and there are existing facts to substantiate it—a large salt lake existed in Cheshire, probably connected in the wet season with a chain of lakes of a similar nature extending to the mouth of the Severn. The formation of salt in the dry season conclusively proves that the climate differed from the present, that in fact it was semi-tropical, and had its hot, dry seasons of no rainfall, followed by copious rains. During the rainy season the waters of the lake would spread over an extensive area. In the dry season evaporation would proceed at a rapid rate, and the lake would shrink on all sides and occupy a very much more limited space, being confined to the lowest portions of the area, and would then form a series of smaller lakes of brine occupying the hollows of the land. This process can be seen annually in India, at Lake Sambhur, which in the wet season is 20 miles long by 5 wide, whilst "in the hot season, as a rule, the lake contains no water, but presents a mass of dazzling roseate white efflorescence caused by the crystallization of the salt; here and there this monotony is relieved by patches of brine in course of evaporation."* There are many salt lakes in the neighbourhood of the Caspian Sea and in Central Asia, which also show us the process of salt formation. The salt then forms crystals on the bottom and sides of the lake, which crystals keep growing as the evaporation progresses. At this stage the crystals present a beautiful appearance, having sharp edges, and growing into and upon one another at all angles. When the rainy season sets in a great change occurs. The streams and brooks, which were dry in the hot season, now run like torrents, bearing with them mud and sand. The sandy and heavy portions deposit at the mouth of the stream, where the salt is soon all eaten away by the fresh water. The fine mud or clay is carried over the area to long distances. The fine, sharp angles of the salt are eaten away, and the

* "Notes on the Birds of the Sambhur Lake, and its Vicinity," by R. M. Adam.

mud settles amongst the crevices and interstices of the crystals. Here and there sufficient mud falls and buries a crystal before the action of the water has spoiled it, and it remains to this day in the salt to show what the crystals were.

(Specimens of crystals formed by evaporation in a miniature lake in a salt mine are pure and perfect, no stream of muddy water having destroyed their beauty.) The rainy season swells the area of the lake, and the fine mud is deposited over a far more extensive area than the salt deposit. The dry season again returns, the same process follows, and the bed of salt continues to grow. If a season is less than usually wet, the salt is purer and has less clay in it. If, on the contrary, the season is abnormally wet, the clay is more abundant, and the salt is only in small quantities. An inspection of a salt bed will clearly show the greater or lesser period of rainfall. From this it will be evident, then, that the beds of rock salt are really composed of salt and clay, and this is the fact. At times clay prevails, at others salt. It is very difficult occasionally to tell whether the specimen examined is a mass of clay with a little salt in it, or a mass of salt with much clay in it. A salt bed often varies from 99 per cent. of salt and 1 per cent. of clay, to 99 per cent. of clay and 1 per cent. of salt. The salt bed almost always terminates in a bed of marl, showing that the rains predominated, and the seasons were not dry enough for salt to form. In Cheshire the lower bed of salt was followed by some 30 feet of marl, with very few traces of salt, then salt commenced again and continued for some 70 or 80 feet, after which marl followed, and no more salt. It will be evident now why the beds of salt cannot be coextensive with the marls, but must have been formed in the lowest portion, or portions, of the much-diminished lake. As the beds of salt formed on the bottom they would naturally take the shape of the bottom in their lowest portions, while the top would keep a fairly level form. Thus, around the edges of the salt— or what we may call its subterranean " out-crop,"—the bed of

salt would be thin, getting thicker towards the middle of the bed. This is a fact well known in Cheshire.

From the great thickness of Keuper Marls above the beds of rock salt in Cheshire (varying from about 100 feet or more in some portions of the district, to 200 feet or more in other portions), it is evident that the salt lake had become comparatively fresh, and remained as a lake for many ages. In one or two isolated spots in the immediate neighbourhood of the Red Marl area there are deposits of Lias, whilst generally speaking, the Boulder Clays and sands are immediately overlying the saliferous Keuper Marls.

Having seen the position and method of formation of the beds of rock salt, we shall be able to understand how they become denuded or water-worn. Water is a most powerful solvent of rock salt. Probably there is no other rock in the earth's crust so easily acted upon by water as rock salt. Water, as is well known, is the most powerful agent in the denudation of rock surfaces. It acts in two ways: either as a mechanical agent, carrying away in *suspension* particles of rock, or as a solvent, carrying them away in *solution*. In *sub-aërial* denudation water acts in both ways, but more largely as a mechanical agent. In subterranean denudation it is almost, if not entirely, a solvent, carrying away the rock in solution. It is important to bear in mind the distinction. Salt is not carried away in suspension by water and deposited when the water becomes still, like marls, and clays, and sands, but is held in solution and not deposited, unless, by the reduction of the water by evaporation, a state of super-saturation is produced; then the particles of salt crystallize out. If we put saturated brine, that is, water which has taken up in solution between 26 and 27 per cent. of chloride of sodium, into a bottle and cork it up, or close it, so as to prevent evaporation, no salt will fall or deposit however long it remains so closed up.

Salt beds, like all other beds of rock, are liable to be reached by fresh water and in many cases are so reached. The upper bed of rock salt in Cheshire is reached by fresh

water from above—undoubtedly the rainfall of the district. The lower bed is not so reached, consequently, all the denudation occurs on the surface of the upper bed of rock salt.

The action of fresh water upon a bed of salt is very rapid and continues until saturation takes place, when no further solution of salt occurs. As long as the saturated solution remains on the salt rock, further denudation is prevented, but, if by any means motion is established, then the water saturates itself as it passes along, and as long as the flow of fresh water continues, so long will the denudation go on.

Salt rocks occur in all positions, some in the heart of lofty mountains, as in the Tyrol and Salz-Kammergut; others as hills exposed to the weather, as at Cardona in Spain, and in the district of Kohat, in N.W. India; bnt the generality are below the surface of the earth, often at very great depths. It is not intended to deal with the denuding effects of water in all these various position of salt beds, but, simply with the case of those in Cheshire. These lie at depths varying for the upper bed from 40 to 60 or 70 yards from the surface, and for the lower, from 80 to 100 yards.

The marls overlying and underlying the salt beds are almost water-tight, though here and there permeable strata occur. If by any means water reaches the rock salt, it will saturate itself and remain unmoved, and the other fresh water following after it will only slightly diffuse itself with it. The specific gravity of saturated brine is 1·2, and fresh-water will swim upon it, diffusion only taking place so extremely slowly where there is no motion of the water, that practically the lower stratum of brine always remains fully saturated, As the water reaching the Cheshire salt bed proceeds from a considerable elevation, the pressure forces the saturated brine upwards through any portion of the marls that may be permeable till it appears at the surface as a spring of brine or salt water. If the salt contained in the brine had been held in *snspension* and not in *solution*, it would have been deposited amongst the marls, sands, and earths through which it had *passed. Brine* springs are common in almost all countries

possessing beds of salt, and Cheshire in olden times had a number making their appearance in the valleys of the Weaver and Dane. These springs indicate a movement of the water, and as they contain salt in solution they prove also that denudation of the salt beds is taking place. There are, however, several things to be noted respecting these natural springs. They are rarely if ever fully saturated; they are not often very copious, or if they are, they hold but little salt in solution, and the denudation caused by them is so slight as not to be perceptible in a lifetime. These are points which I have carefully considered and proved elsewhere,* and I must ask you to take them as the generalisation of a large number of facts. Naturally then we should not expect visible denudation, that is, we should not expect to see by the sinking of the surface that underground removal of rock surface was taking place, where only natural brine springs exist. This is so, for we have no satisfactory evidence that either in Cheshire, or in any other part of the world, visible subsidence is being caused purely by natural subterranean denudation on anything but the smallest scale. How then do we account for the enormous subsidences in Cheshire? Very simply. The ordinary operations of nature are accelerated to an enormous extent by the creation of a number of artificial brine springs, discharging saturated brine at the surface. These springs are far more numerous than the natural ones—far more copious in their flow, and contain a far greater per centage of salt in their brine. In Cheshire at present, nature supplies the fresh water, but man assists nature in removing the saturated solution. To such an extent is this now the case, that in the districts where man supplements nature—natural springs have been entirely superseded by the artificial ones, the level of the brine standing many yards below the surface. For about a century, man has taken by his artificial springs or pumps more brine than nature originally got rid of in brine spings. No sooner did man commence to do this, than visible subsidences begun,

*"On the Action of Water upon Beds of Rock Salt." Proceedings of *Lit. and Phil. Soc.*, Manchester, Vol. xxiii., No. 2, Session 1883-4.

and in proportion as man has increased his pumping, so has visible subsidence followed, showing the extent of denudation of the surface of the subterranean salt beds. It is only in those districts where man has taken away large quantities of brine that very serious subsidences have followed. There is no mystery whatever in the matter, there is nothing at work but ordinary geological causes, but in this case accelerated to an alarming extent by the action of man.

It is about a century since the first subsidences that can be clearly connected with brine pumping occurred, and now they go on increasing from day to day. The quantity of salt annually extracted from the brine pumped up, will give an idea as to the amount of denudation annually occurring in Cheshire. In the "Mineral Statistics of Great Britain and Ireland" for 1882, the quantity of white salt, that is salt made from brine in Cheshire, is given as 1,580,000 tons in round numbers. This means a denudation of 204 acres of salt surface 1 yard deep; or, to put it more simply, the amount of denudation might be represented as the channel of a river 60 feet wide, 9 feet deep and about 9½ miles long. In some tables prepared for a Committee of the House of Commons, it was stated that the quantity of salt made from brine, exported from the Mersey during the ten years ending 1880, amounted to 9,067,468 tons, which would require a denudation of 1,170 acres of salt surface, one yard deep, that is nearly two square miles. Put into the form of a river, this would give a channel 60 feet wide, 9 feet deep, and about 54 miles in length. The shipments for 1883 from the Mersey, would form a denudation channel six miles in length, 60 feet in width, and nine feet deep. Year by year, we have an enormous amount of subterranean denudation, which shows itself by the sinking down of the overlying earths into the troughs or synclinals formed by the wasting away of the rock surface. There are going on before our eyes, and at our very door, changes of a geological nature that compress into the space of a few years what nature unaided by man would only accomplish in ages.

To make the paper more complete I will give a short

description of the subsidences in the two salt districts of Winsford and Northwich. At Winsford it was not until the early part of the present century, near the year 1820, that any subsidences were noticed, as prior to this the amount of pumping had been small. The chief feature of the sinking is the formation of a synclinal, of which the River Weaver, southward of Winsford, forms the lowest part. This synclinal has gone on increasing in depth, length, and breadth, year by year, forming a large lake. Another synclinal commenced to form later on still further up the Weaver. This, like the former, still continues to increase in area and depth. The two lakes, called locally "Flashes," are approaching each other, and are now about 100 acres in area. Tne Lower Flash has approached close to the town, and shops and houses are being taken down and rebuilt. A fine stone church had to be taken down and the new iron church substituted for it, has recently been lifted. Another line of sinking extends up a small brook valley past the Bradford Mill. Owing to some peculiarity of the ground, the subsidences in this direction do not form such perfect synclinals as in the Weaver Valley. It would seem as if the denudation went on and the overlying earths remained suspended over the wide synclinal forming on the bed of salt until the span being too wide for the earths to support themselves longer, a sudden, huge, and violent fall of tens of thousands of tons of earth takes place, driving before it or forcing out, even at the surface, the imprisoned brine and water, and forming huge pits or holes which soon become filled with water. There are other portions of this district subsiding and lakes and pools forming. The area of subsidence is comprised within about six square miles, but only portions are affected.

At Northwich, which is better known than Winsford, though not pumping so much brine, the subsiding area is comprised within two square miles and, being more contracted, its effects are more visible and serious. Another cause for the more exaggerated form of the Northwich sinking is the number of old salt mines that have been given up and into

which the water has penetrated. At Northwich what was a small brook a century ago, is now a huge lake of 100 acres in extent, and in places 40 to 50 feet deep. Within 200 yards of this another lake of over 10 acres has been formed within ten years. This is as deep as the other, or even deeper. It extends to a public highway, and the road has sunk fully 40 feet in about six years. Since 1880 another lake has formed, and is still increasing. It is about five acres in extent, and in some places 60 or 70 feet deep. Besides these lakes, lines of subsidence cross the streets of the town, destroying houses and shops to an enormous extent. All the most valuable business portion of the town is affected. Every year fresh lines of subsidence occur, and new synclinals cross the roads and streets. The effect of these is evident, for the houses on both sides of the synclinal slip towards the lowest portion of the trough, splitting and cracking from one end to the other. A visit to Northwich is one well worth paying, as the results of subterranean denudation are exhibited upon a scale of such magnitude as to impress every one with the vast powers of water acting upon easily-soluble rock surfaces.

Specimens of rock salt and marls, denuded and undenuded, were exhibited by the Author in illustration of his paper.

LIVERPOOL GEOLOGICAL ASSOCIATION.

February 9th, 1884.

VISIT TO THE MUSEUM.

The THIRD visit of the series took place this date. The members met in the "Stone Gallery" of the Museum, William Brown Street, when an Address, illustrated by specimens, was given by MR. DANIEL CLAGUE, on

"A Study of the Palæozoic Fossils."

March 3rd, 1884.

At the Ordinary meeting held this date at the Free Library, MR. HENRY BRAMALL, M. Inst., C.E., President, in the Chair, the following were elected as Members:—

Messrs. Peter H. Walsh, F.C.S., and J. M. Labouchere.

Proposed as Members:—

Messrs. Coard Squarey Pain, Assoc., Inst., C.E., 14, North John Street, and C. E. Mannington, 59, Orwell Road, Liverpool.

DONATIONS.

"The Geology and Volcanoes of Central France, by G. Poulett Scrope, *presented by Mr. T. R. Connell;* "Proceedings, Liverpool Literary and Philosophical Society," Vols. 35, 36 and 37, (for 1880-1, 1881-2, 1882-3); Ditto, Liverpool Astronomical Society, Jan. 1884; "Annual Report," 1883, Liverpool Engineering Society; Ditto, 1883, Lancashire and Cheshire Entomological Society; "Transactions," Royal Geological Soeiety of Cornwall, Pt. 6, Vol. x; Ditto, Manchester Geological Society, Pt. 13, Vol. 17,-*presented by the respective Societies;* Papers by Isaac Roberts, F.G.S. F.R.A.S.,—On Wells and Water of Liverpool; On Strata and Water-level at Maghull; On Experiments in filtration of Water; Boring on East Hoyle Bank; Pressure of Wheat stored in elongated cells; On a new Planet Indicator; Presidential Address on "Volcanoes and Volcanic Action,"—*presented by the Author*; Paper on "Miniature Domes in Sand," by T. Mellard Reade, F.G.S.;—*presented by the Author*; Geol. Survey Maps, Q.S. 81 S.E. and 81 S.W. (Buxton)—*presented by Mr. George Lewis.*

The following Paper was read on—

MINERAL SPRINGS.

BY CHARLES E. MILES.

Natural springs emanating from the earth's surface have their origin in one common cause, the circulation of underground waters.

In the first instance, aqueous vapour ascending from the ocean by evaporation, and conveyed by the atmosphere, finally falls as rain upon land surfaces. A portion by percolation through the soil reaches the underlying rock, where a variety of conditions are open to receive the waters thus collected. The rocks beneath the surface of the soil may be very porous as gravels, sandstones or chalk, or they may be ccmpact rocks as granite. Again some of the porous rocks have impermeable strata as clays inter-stratified, which offer resistance to the flow of water, and the whole may be broken and disturbed by faults. Entering a permeable bed, water would be absorbed into its substance, as well as find its way down through cracks and fissures of the rock. On reaching an impermeable bed, however, the descending waters would be arrested, and collecting on its surface would spread along until a further vent was found.

It is known that all rocks contain water absorbed into the interstices existing between the particles of which the rock is composed. Prof. Ansted in his Lectures on Practical Geology states that "Even the driest and most compact marbles in their driest state hold from ·4 to 4 per cent by weight in their composition. Some granites in the ordinary dry state contain one pint and a half of water in every cubic foot, and are capable of absorbing half a pint more". He also states that ordinary sandstones may contain one gallon of water in a cubic foot. The least absorbent of the common limestones of England holds from four to five pints in the cubic foot, while chalk is very absorbent taking up half its own bulk of water, or two gallons of water to the cubic foot. It is asserted that none of the rocks commonly met with near the earth's surface contain less than two pints of water in every cubic yard.

That water also circulates under the surface of the ground is undoubted. Where the underlying rocks consist of chalk or *limestone* there is every probability of large underground

watercourses existing in such localities, as flowing water containing carbonic acid in solution is capable in time of dissolving out such passages. But Sir Charles Lyell in his Principles points out that in boring for Artesian wells, it has been found that open passages exist in strata of different ages and composition through which waters circulate underground.

The different physical circumstances under which natural springs exist give rise to springs which differ very considerably in their character, but geologically speaking they may be referred to three classes.

The most simple form of spring is found where beds of sand or gravel rest on impermeable strata, as clays. Such springs fluctuate according to the humidity of the seasons, they do not generally rise from any great depth and have been termed land springs. Somewhat similar springs issue from strata where the permeable beds instead of gravels consist of sandstones or other porous rocks. Owing to most strata being inclined to the surface and faulting causing complications in the beds, water in passing through such rocks may sometimes travel some distance underground before emerging in the form of springs. Water does so eventually emerge at a lower level than the point where it entered the surface and often by means of a fault which acting as a wall causes the flowing waters to ascend as springs.

The second class are called Artesian springs, deriving their name from the province of Artois, France, where water has been raised very successfully from borings in the strata. The principle as in the first class lies in the fact of water bearing strata being supported by an impermeable stratum, or a series of such beds alternating, the whole forming a geological basin the edges of which crop out to the surface. The outcrop of the permeable bed or beds which may be very considerable in extent absorb surface waters. These waters sink to a lower portion of the basin, where if a fault occurs they may rise to the surface as springs. This form of spring is usually more constant in its supply than the first class as the field of drainage is generally greater, but its supply is practically lim-

ited, being fixed to one area. The temperature of the issuing waters is usually constant and frequently above the ordinary springs and mean of the district in which they are situated.

The third class of springs are Mineral springs, and these generally are found to occur in such districts where great disturbance in the strata has taken place.

Mineral springs have been so termed on account of the large proportion of mineral salts held in solution by them. In addition they may also hold certain gases, acids, bitumen and organic matter. The mineral contents have in many cases given to such springs valuable therapeutical properties. Generally they are also thermal or have a higher temperature than ordinary springs, or the mean annual temperature of the district where they occur. Thermal springs, however, are not always mineral springs, but as the two properties frequently are found together they will be here classed as one.

These peculiar springs are found in most countries and at all levels above the sea, but they are usually most abundant in mountainous regions, as the Pyrenees, Alps and Himalaya Mountains, and also in the neighbourhood of volcanoes. In mountainous regions they emanate at the points where granite and metamorphic rocks come to the surface in contact with another rock of dissimilar character. It is mentioned by Prof. Jas. D. Forbes that amongst all the nuclei of hot springs in the Pyrenees which he visited there was no exception to this rule.* In that district they all occur where granite comes to the surface in contact with a stratified rock as slate or limestone. The celebrated springs of Carlsbad in Bohemia originate along a line of contact of two granites of different geological age. Lyell states that in cases where Mineral and Thermal springs occur away from present centres of volcanic energy, they break out along lines of upheaval, where dislocations open out a passage from considerable depths to the surface. The locality of these springs thus appears peculiar to those regions which have suffered great disruption of the strata. A large number of mineral springs found in

* Phil. Trans., 1836, Temp. and Geol. relations of certain hot springs.

Europe have been described, but some of those occurring in the British Isles possess points of great geological interest.

Mineral springs vary very considerably from each other in the quantity of water they emit, the temperature at which they reach the surface, and their mineral contents. Compared with ordinary springs the volume of water given out is generally greater and the quantity is less liable to change at different seasons.

There can be no doubt that the hottest springs are those directly connected with active volcanoes, but many are found over 120° F. in localities which are a considerable distance from centres of volcanic activity, and in which no igneous rocks are found. In the latter case there is generally evidence found of large dislocations in the rocks of the district, as for instance at Clifton, and also at Bath where De la Beche points out there is to be found evidence of faults, some of considerable size, having been formed in the older rocks of that district anterior to the accumulation of the New Red Sandstone and Oolitic series which now overlie them.* Although the great majority of Thermal springs are below 100° F., many no doubt would have a higher temperature but for the obstructions to heat, met with in the strata in passing through. In England the hottest are those occurring at Bath, the mean temperature of which is 120° F., and Sir Charles Lyell points out that this temperature is exceptionally high also in Europe, taking into account their distance from any volcanic centre of recent geological times. The Buxton spring has a temperature of 82° F. Like volcanoes, but in a quiet unobtrusive manner, Thermal springs serve in the economy of nature for the conveyance of heat from the interior of the earth.

The matter contained in solution by mineral springs is of a varied character, though the number of those substances found in abundance is small, and very few are thrown out as deposits. A large variety of substances, however, have been found in minute quantities, chemical research tending always to increase the list. Prof. Ansted enumerates a number of the bodies

* Geological Observer, p. 466.

met with. The Acids commonly found are Carbonic dioxide, Sulphuric, Hydrochloric, Silicic, then Hydrobromic, Hydriodic, Boracic, Nitric, Phosphoric, and Arsenious. In some springs some of these acids occur in a free state, the acids being in excess of the bases. Organic Acids are occasionally met with. The chief bases found are those of the alkalies and alkaline earths, viz., Soda, Potash, Lime, Magnesia, Lithia, also the oxides of Rubidium and Cœsium, together with Alumina and the oxides of Iron and Manganese. Copper is also rather a common constituent, whilst among the metals more rarely occurring may be mentioned Mercury, Cobalt, Nickel, Tin, Titanium, Antimony, Zinc and Gold: Barium and Strontium also occur.

Carbonate of lime is a very common and abundant constituent of mineral springs. In limestone districts calcareous deposits from springs are common, but carbonate of lime is also deposited from mineral springs in districts bare of limestone. Sir Charles Lyell points out that in Central France where the primary rocks are unusually destitute of limestone, springs copiously charged with that substance rise up through the granite and gneiss.* Scrope mentions that in the fissures of some of the travertines of the same district, Arragonite is occasionally found to have crystallized.

Sulphate of lime commonly occurs in mineral springs. Fluate and Phosphate of lime exist, but are less abundant than the Sulphate. The Vichy waters contain the fluate salt.

The salts of Soda, Carbonate, Sulphate and Chloride are common to nearly all mineral springs, and the quantity of Carbonate of Soda held in solution by some springs is very considerable. Sulphate of Soda sometimes replaces the Carbonate and preponderates, the Cheltenham waters containing 150 grains to the gallon. Lyell mentions a hot spring rising through granite at St. Nectaire in the Auvergne district, which contains together with other salts a large proportion of Chloride of Sodium. The Carlsbad waters have been calculated by

* Principles, Vol. 1, P. 401.

Gilbert to bring annually to the surface 8928 tons of Sulphate of Soda, and 5808 tons of Carbonate of Soda. It is a point worthy of note, that Soda salts are found so plentifully in mineral springs, while on the other hand Potash salts are either absent altogether, or are found in small proportion only. The thermal springs of California commonly contain potash salts in quantity, but potash seems less common than lithia, which is found to exist in most mineral waters in small or greater quantity. Where the soda springs are thermal, Silica sometimes exists in the waters in large quantity. Peroxide of Iron is also often found associated with Carbonate of Soda in mineral springs, the iron being held in solution by excess of Carbonic dioxide.

Silica when found in mineral waters chiefly occurs in hot springs near volcanoes, and is deposited from such waters on evaporation. In this manner large deposits of Siliceous sinter are produced.

Iron being a very common constituent gives rise to the term Chalybeate which forms a numerous class of mineral springs. The iron held in solution as Bicarbonate, although not usually large in quantity, is generally present sufficiently to form rusty ferruginous deposits of the peroxide. Manganese is commonly met with, but usually in small amount.

Salts of Magnesia are widely distributed in mineral springs. The most common salts are the Bicarbonate and Sulphate. Sea water contains from 150 to 500 grains of the Sulphate to the gallon, while the Seidlitz waters in Bohemia contain a very large quantity, 2000 grains per gallon.

The gases held by mineral springs are remarkable in their character. These gases frequently come bubbling to the surface of the waters, at times giving to them the appearance of boiling. Carbonic dioxide, Nitrogen, and Sulphuretted hydrogen are very common, Oxygen only occurs in a small proportion, Ammonia is also detected, while free Hydrogen appears absent altogether. Of the gases which escape in bubbles, Dr. Daubeny states in his work on Volcanoes, that

Nitrogen is the most generally detected, and is so very common to thermal springs, that he regarded it as a constant concomitant, having examined a great number. The most abundant evolution of this gas he found to occur at the Bath springs, where from the thermal waters of the King's Bath, he found it to average not less than 222 cubic feet daily. This evolution varied from time to time, but the gas was nearly pure being Nitrogen 97 °/o Oxygen 3 °/o with a small but variable amount of Carbonic dioxide. Nitrogen is also given off from the warm springs of Buxton, Bakewell, and Stony Middleton. The same thing was found at Taafes Well near Cardiff, and the tepid waters of Clifton. Daubeny also points out that it has been detected in almost all the thermal waters of the Pyrenees, and also in many of the thermal waters of France, as Mont Dor, Aix la Chapelle, the latter place giving of the total amount of evolved gases 82 to 87 °/o of Nitrogen. At Kissengen in Bavaria, several cold springs occur which give a copious discharge of gas, viz., Carbonic dioxide 25·45, Nitrogen 66·50, Oxygen 8·05. Near Inverkeithing in Scotland, a cold spring is found emitting Nitrogen.

Sulphuretted hydrogen is commonly found in thermal waters, and according to Daubeny is found in almost all those met with at the foot of the Pyrenees, also in those of the Andes. Sulphate of lime is very common to those springs where sulphur exists in any quantity. Sulphuretted hydrogen rising in bubbles is frequently set free from mineral springs.

Carbonic dioxide is almost always present in greater or less abundance in mineral waters. A remarkable disengagement of this gas is mentioned* by Prof. James Forbes occurring at Kissengen, where a spring which gives off this gas has its regular periods of intermittence and of agitation, evolving enormous quantities, and giving the surface of the water, eight feet in diameter, the appearance of a pan of boiling water. Whilst the turbulence is at its height the gas abruptly ceases to flow, and the surface of the water becomes almost immediately tranquil. It should be noted that springs near active

* Memoir Edin. Phil. Jour'l, 1839.

or extinct volcanoes plentifully discharge this gas. In such districts it is often disengaged from the soil also. It has been noticed that the greater the amount of Carbonic dioxide in mineral springs the greater is the amount of alkaline bicarbonates in solution.

In the United States many remarkable mineral springs exist. Some of these described by Mr. J. A. Phillips* are of great interest. The Steamboat springs, which are found near Virginia City in the State of Nevada occur in granite and are 5000 feet above the sea level. The issuing waters are slightly alkaline and contain Carbonate of Soda, Sulphate of Soda and common Salt. Carbonic dioxide and Sulphuretted hydrogen are given off from certain points in notable quantities, while Silica, Sulphur and Oxide of Iron are deposited. In volcanic districts Solfataras exist, which are vents from which issue steam and gases, principally Sulphuretted hydrogen and Sulphurous acid. By mutual chemical reactions occurring in the issuing vapours, Sulphur is deposited. A solfatara some six or seven acres in extent, described by Mr. J. A. Phillips, occurs in a much decomposed volcanic rock on the shores of Clear Lake, California. Innumerable fissures traverse the ground from which Steam, Carbonic Acid, and Boracic Acid continually issue, Sulphur is deposited on the sides of crevices. Chalcedony, Opalescent Silica and Silica frequently permeated by Cinnabar and Iron Pyrites or blackened by a tarry hydrocarbon are deposited, and concretionary masses of Cinnabar of considerable size are found.

Solfataras appear to be the connecting link between violent volcanic action on the one hand, and the quiet effect of mineral springs on the other, with regard to the substances brought by them to the surface. It being found that the gases evolved by volcanoes correspond remarkably with the impregnations of mineral springs. Volcanoes among other things emit Hydrochloric acid, Sulphurous acid, Sulphuretted hydrogen, Carbonic dioxide, Boracic acid, Hydrogen, Nitrogen and Ammonia, almost all of which are found also in mineral

* Phil. Mag. 1871, No. 42.

springs. Dr. Daubeny strongly asserts that the origin of both phenomena is due to the same cause. Sir Charles Lyell also says that in many volcanic regions, jets of steam issue unceasingly from fissures at a temperature high above the boiling point, and if such columns of steam, which are often mixed with other gases, should be condensed before reaching the surface by coming in contact with strata filled with cold water, they may give rise to thermal and mineral springs of every degree of temperature. He also states that by such means rather than by hydrostatic pressure, in many cases the rise of large bodies of water from great depths can best be accounted for.

If the origin of mineral springs is due to the same cause as that of volcanoes, it is not sufficient to state so, for from what cause do volcanoes originate? Certainly we are not without theories, but which, if any, is the correct one. But a study of the phenomena of mineral springs, affords us information as to the condition of the interior of the earth, from which they rise, not given by a similar study of volcanoes, although they both serve in a manner to bring matter from beneath to the surface.

The evidences afforded by mineral springs of the changes now taking place beneath the surface of the earth are both valuable and interesting. A point mentioned by Daubeny is, that if thermal springs derive their temperature from a remnant of volcanic energy existing beneath, they ought to be met frequently in countries where such energy has at one time or other been manifested, but if they simply proceed from a *generally diffused heat* pervading the interior of our planet, then they may be met with in countries of every geological age. In point of fact hot springs are abundant in volcanic regions, no such region apparently being without them, but away from these districts their number decreases. On the other hand while in volcanic districts the temperature of thermal springs is sometimes subject to change, owing to disarrangement from earthquakes, in countries not at present exposed to volcanic operations, the temperature of these springs during a long

period of time appears to undergo no change. It is interesting to notice the salts and gases held in solution by mineral springs, and the sources from which they are probably derived. All rocks contain a certain amount of soluble matter which water would take up in passing through, common salt is one. But this does not account for the prevalence of soda salts, and the comparative absence of potash salts in mineral waters. One or two reasons may be given in explanation.

Potash as a constituent of the felspars is widely disseminated through the rocks. Bischof and others have shown that after long boiling, water alone will separate alkali from volcanic tuff, but the process is facilitated by the addition of Carbonic dioxide. Also, if this gas is slowly passed through distilled water containing pieces of granite, alkali from the felspars is dissolved out. In nature the continued action of water charged with Carbonic dioxide upon felspars, results in their decomposition, and the production of alkaline carbonates which are carried away in solution. Of the Carbonates thus produced, that of potash is the most soluble, and if no other influences were at work, might remain in solution until the waters became so fully charged with this salt as to cause the precipitation of other alkaline carbonates contained therein. Carbonate of Soda is less soluble, while the carbonates of lime and magnesia are soluble only in the form of the bicarbonate. It is observable however that orthoclase or potash felspar exposed to atmospheric conditions, is not so subject to decomposition as the lime-soda felspars, as albite, labradorite and oligoclase. While the surfaces of the latter felspars on exposure weather into a white opaque crust, orthoclase remains under similar conditions unchanged. Probably beneath the surface where highly heated waters circulate, lime-soda felspars are much more rapidly decomposed. Daubeny points out* that where as is often the case orthoclase and albite exist together in a granite, the basis generally consists of albite, while the imbedded crystals are those of orthoclase. Such he says is the case at Carlsbad, and he believed that this was the true

* Volcanoes, page 14.

solution to the question, why Carbonate of soda is so common a constituent of mineral springs to the exclusion of Carbonate of potash, the potash felspar crystals offering more resistance to solubility. It has been argued by others* that when waters containing with other things salts of potash in solution, come into contact with argillaceous strata, they part with their potash to the argillaceous sediments, owing to the action of hydrated double aluminous silicates contained therein, while under ordinary circumstances neither soda, lime nor magnesia is parted with in this way, and the comparative absence of potash salts in mineral waters is thus accounted for.

Then again if the nitrogen gas which escapes from mineral springs has entered the ground with surface waters as atmospheric air, what has become of the oxygen. This is an important question, when it is considered that although in bulk the latter gas forms only about one-fifth of the atmosphere, it is soluble in water to about double the extent of nitrogen. It must not be forgotten, however, that where water may go, atmospheric air will travel also, and the rocks themselves near the surface to some extent must be aerated. If this is the case the fact remains that oxygen enters the earth and there disappears.

It has been brought forward that mineral springs derive their ingredients from sea water, which entering through fissures in the bed of the ocean finds its way to the surface of the land by means of springs. There is evidence that this theory is not unreasonable. At Huel Seton copper mine† one mile N. E. of Camborne, Cornwall, and three miles from the sea, a fault occurs which the mine has intersected, and this fault can be traced in a northerly direction to the sea. The mine is worked in the clay slate, granite being in the neighbourhood. From the fault in the mine a hot spring gives out 50 gallons of water per minute at a temperature of 92° F., and contains above 1000 grains of solid matter per gallon, the greater portion of which is made up of chlorides, that of calcium preponder-

* Chem. and Geol. Essays, Dr. T. Sterry Hunt, page 95.

† J. A. Phillips, Phil. Mag., 1873.

sting, Calcium chloride represents 478 and Sodium chloride 409 grains. The spring also contains over 34 grains of Lithium chloride and some free Carbonic dioxide. A similar hot spring formerly issued at Huel Clifford mines, 1320 feet below the sea level. Mr. Phillips shows that, if sea water does enter into the composition of the Huel Seton mineral water, in passing through the rocks, its constituents have undergone some change; Chlorine has been augmented, its Sulphuric acid is almost lost, while Carbonic acid is taken up, Magnesium has been abstracted and Calcium added, and Lithium has entered into solution.

Bromine and Iodine which are found in sea plants and sea water occur also in mineral springs, Iodine having been found in a spring in the Andes, 80 or 90 miles from the sea, and 10000 feet above its level. These constituents occur also in springs from the Lias at Leamington, Gloucester and Cheltenham.

Whether mineral and thermal springs are the last efforts of expiring volcanic energy, or whether their phenomena are due to other causes, much remains yet to be known about them. But the lessons they afford may perhaps lead to a riper knowledge of the conditions which exist beneath the surface of our planet, not otherwise obtainable.

LIVERPOOL GEOLOGICAL ASSOCIATION.

March 6th, 1884.

VISIT TO THE MUSEUM.

The last of the Winter Series of Visits to the Free Public Museum, William Brown Street, was held this date. The members having met in the "Stone Gallery", an illustrated Address was given on—

"The Fossils of the Oolitic and Cretaceous Periods,"
By Mr. Thomas Brennan.

April 7th, 1884.

At the Ordinary Meeting, held this date in the Free Library, Mr. Henry Bramall, M. Inst., C.E., President, in the Chair, the following were elected as Members:—

Messrs. C. E. Mannington, and Coard Squarey-Pain, Assoc. Inst., C.E.

Proposed as Members:

Rev. S. Gasking, B.A, F.G.S, 11, Russell Road, Garston; Mr. Edmund Dickson, West Cliff, Preston; and Mrs. B. Cotter, 10, Oxford Road, Waterloo.

DONATIONS.

"Proceedings," 1883, Manchester Scientific Students' Association; "Report and Proceedings," 1882-83, (Pt 3, Vol. II, Series II) Belfast Naturalists' Field-Club; 'Annual Report", 1883, and "Proceedings" No 4, Vol. 8, London Geologists' Association; "Proceedings", Feb., 1884, Liverpool Astronomical Society; "Transactions", (Pt. 14, Vol. 17,) Manchester Geological Society,—*presented by the respective societies*, "Annual Report", 1883, Liverpool Free Library, Museum and Art Gallery,—*presented by the Librarian*; Paper on "Cambrian Conglomerates", by Dr. Henry Hicks, F.G.S.,—*presented by the Author*; Paper on "The determination of pressures of granular substances", by Isaac Roberts, F.G.S., *presented by the Author.*

COMMUNICATION.

Mr. J. R. Webb drew attention to a section exposed in a lane near Mount House, Storeton, showing Keuper basement beds resting upon Upper Mottled Sandstone, and bounded on the west by a fault. A drawing of this section, and specimens of the rocks were exhibited by the Speaker.

The following Paper was read on—

"THE PROPERTIES OF TRIASSIC SANDSTONE,"

By Isaac Roberts, F.G.S., F.R.A.S.

The Geologist, if he should aim at being entitled to more than the name, ought, in addition to having a clear knowledge of the positions and sequence of strata and their contained fossils, to know the properties and uses of the various rock masses which include the objects of his study, and on the principle here stated in a general sense, I propose in this communication to give some particulars of the investigations, (which have occupied more or less of my attention, during the past twenty years and upwards,) of some of the properties and uses of the Triassic Sandstone.

I will assume that the Geological position of the Trias is well known, and will now only state, that it forms the uppermost rocks in Lancashire, between Garstang on the North, and the River Mersey on the South, and between the Irish Sea on the West, and the coal fields of Wigan and St. Helens on the East.

In Cheshire they extend from the peninsula of Wirral on the North, to near Shrewsbury on the South, and on the East and West they extend between the Flintshire and Staffordshire Coal Fields.

The rocks differ widely in physical character, and indicate aqueous conditions between still water and water agitated or in rapid motion. The shales of the Keuper are formed of mud in a state of almost impalpable powder, which would require still water for deposition. The upper and lower Bunter are generally made up of fine grains of quartz sand indicating that they were either blown by wind or deposited in water that was but little disturbed, or, as Prof. Geikie has pithily described it, "The ancient Dead Sea wherein these red rocks were accumulated." The lowest beds of the Keuper and the Pebble beds of the Bunter indicate water in considerable agitation.

Within a radius of ten miles or less of Liverpool, are found all the divisions of the Trias from the upper Keuper to the lower Bunter, excepting of course the Muschelkalk. At Runcorn is a thick deposit of Keuper shale; at Storeton and *Bidston*, in Cheshire, are the lower beds of the Keuper, the

lowest generally being a rough rock containing large grains of sand, numerous quartz pebbles and nodules. This division of the Keuper is also found under parts of Liverpool, where also the upper Bunter and the middle or pebble beds are largely developed.

Following are the estimated thickness of the Keuper and Bunter Sandstones in Lancashire and Cheshire

Red Marl - - - - - -	3000 feet.
Lower Keuper Sandstone - - -	450 feet.
Upper Mottled Sandstone- - -	500 feet.
Pebble beds - - - -	500 to 750 feet.
Lower Mottled Sandstone- -	200 to 500 feet.

The lower Keuper Sandstone and the Pebble beds of the Bunter are largely used for building purposes. The ashlar work of the *facade* of the Northwestern Hotel in Lime Street, and the exterior of the Custom House, the Town Hall and the Conservative Club are of lower Keuper Sandstone, which partly was quarried at Storeton, and partly at the Mount Cemetery. The Red stone in the building at the corner of Dale Street and Stanley Street was obtained from the Keuper at Runcorn. The Red stone that is largely used as window heads and sills, and as factable on the gable ends, and strings and cornices of the Houses in Everton, and also the exterior of the Sailor's Home in Liverpool, has been quarried in the Bunter pebble beds of Everton and Woolton. The Red moulding sand that is used in foundries for casting metal is obtained from either the upper or lower Bunter. The rock salt whether dug in lumps or pumped in solution as brine, is obtained from the Keuper in Cheshire. The mortar that is used in the building operations in Lancashire and Cheshire, is largely made of Keuper and Bunter Sandstone ground and mixed with Lime.

Thus we see that the commercial importance of the Trias Sandstone in Lancashire and Cheshire is great, and their employment extensive.

Here are cubes of Bunter and Keuper Sandstone of medium grain. They are compact, hard, free from pebbles, and good samples of the stones as used for building purposes. If we examine this cube under a lens, we shall see that it is made

up of rounded grains of quartz. If we place it under a microscope and use a magnifying power of about forty diameters, we shall see some of the grains to be rounded and roughed like the blown sand on the sea shore, some of them will be like polished crystals with sharp unbroken angles, and some semi-transparent. Between the grains will be seen silica as very fine dust adhering firmly to the grains, this is the cementing material that holds the grains together. It is to the grains which together build up the rock masses of the Keuper and Bunter Sandstones, what the lime is to the sand of which mortar is made—this fine silicious dust is the cementing material which binds together all the Triassic rock masses.

The bottle which I now exhibit contains selected gravel, and when examined it will convey a fairly accurate representation of what this cube of sandstone appears to be when magnified about forty diameters. The grains are in contact with each other, but as they are rounded they have vacancies between them, into which a fluid such as water, or a gas such as air, can enter with considerable freedom. The vacancies or *capillaries* communicate with each other throughout a mass of rock however large it may be, or however extensive may be its boundaries. The capillaries between the grains of sand together with the faults, cracks, or fissures, are the underground reservoirs in which the water is stored, and when a well or borehole is made down into the Trias rocks from the surface of the ground, every foot of surface round the periphery of such well or borehole exposes millions of these microscopic capillaries, and then the water which they contain weeps out, and as all the capillaries in the rock mass are in communication with each other, the weeping will be continuous so long as the level of the water in the well is below that in the rock, and if by pumping, the level of the water in the well is kept below the water surface in the rock, the flow will be continuous towards the well, and when pumping is discontinued the water level will rise again to its normal in the rock.

It might be assumed that the underground water has a *level surface* like that of a lake or pond, but the assumption

would be erroneous, for the effects of friction, and attraction of the capillaries upon the water, are to retard its flow through the rock towards the sea, and cause its surface to rise and form an inclined plane, the lowest edge of the plane being at the sea margin, and its highest surface landwards. The higher Triassic rocks rise above sea level, the greater will be the slope seawards, of the surface of the plane. For instance, at West Kirby in Cheshire the surface of the underground water plane is 29 feet above mean sea level, at the distance of three-quarters of a mile from the sea margin, whilst at Maghull, which is five miles from the sea, the highest surface of the water plane is 58 feet above the sea. West Kirby being on a hill it is necessary to sink a well to the depth of 180 feet in the rock before reaching the surface of the water plane, but at Maghull, which is on a plain the water lies at eight feet be neath the surface of the ground.

The existence of the capillaries in the Trias rocks can be demonstrated without the use of the microscope, and their collective storage capacity can also be measured. If I place this cube of stone so as just to touch some water thus, it will rapidly rise in it, and in a short time the stone will be saturated, the capillaries visibly causing the water to rise above its level. The storage capacity, or the collective measured contents of all the capillaries in this cube of stone can be determined in the following manner:—first dry it at a temperature of about 300° Fahrenheit, then allow it to cool under a close jar, and after cooling, weigh it, then partly immerse it in water, but do not plunge it over head or the air that fills the capillaries cannot escape and consequently water cannot fill them. After saturation, weigh again the stone, and the difference in weight will give the necessary data for computing how much water a cubic foot or any other known mass of such stone as this will store. In this illustration the stone when dried weighed 14553 grains, and when saturated, it weighed 15435 grains, it therefore is capable of storing 882 grains of water in 27 cubic inches, by computing these, we *find that one* cubic foot of stone like this, will store about *seven-tenths* of a gallon of water.

The grains of sand which compose portions of the upper and lower Bunter Sandstone are so regularly rounded that they have been named Millet seed grains. The sand that is quarried for moulding purposes at Town Green near Ormskirk is of this character, and as an illustration, I have here two samples which if examined with a lens will show the character of the grains.

The rate at which water will pass through a compact mass of Sandstone like this specimen, will depend upon the head pressure, and the experiments which I have made to ascertain this, show that with a pressure of one pound on each square inch, $\frac{1}{426}$th gallon per hour will pass through one cubic foot. With the pressure of 10lbs on each square inch, $\frac{1}{72}$nd of a gallon per hour will pass. With the pressure of 20lbs on each square inch, $\frac{1}{56}$th of a gallon per hour will pass. I give these only as approximate results at present, for the experiments are not yet completed.

If the rock mass is made up of larger grains than this specimen, water will pass through much more rapidly. At my residence at Maghull the water will pass through 102 feet of hard, compact, but rather coarse grain rock mass of upper Bunter Sandstone in less than half an hour, and if any faults, cracks or fissures existed in the rock here referred to, the water would flow through more quickly.

The next of the properties of the Trias Sandstone to which I will now direct your attention is the filtering power. If muddy water be poured upon a slab of stone of two or three inches only in thickness, the mud would be filtered and the water would pass through clear. If through a thicker mass of stone a coloured liquid be filtered, the colouring matter would be retained and the water would be clear. If through a mass of stone some three feet in thickness, sea water be filtered, nearly the whole of the salts it holds in solution will be retained by the stone* and this explains why the five or six million gallons of water that are daily pumped out of the wells in Liverpool, is far less saline than sea water, notwith-

*On the filtration of sea water through Triassic Sandstone by the Author. Rep. Brit. Assoc. 1878.

standing the fact that water has for many years been pumped from the wells, which are spread over a surface area of less than three square miles near the River Mersey. The water which still percolates from inland through the rock towards the sea, assists also in diluting the filtered sea water.

Each well in Liverpool draws its supply from two opposite sources, one being the percolation through the mass of the rock from the land towards the sea, the other the sea water which is filtered by the rock, in its passage to the wells. The reason why sea water flows towards the wells in Liverpool, is that excessive pumping from a small area, has lowered the general level of the underground water to a surface that is below sea level, the inclined water plane is therefore reversed, and instead of having the normal inclination seawards it inclines landwards to the wells. If all pumping ceased for a time, the underground water would again rise in the rock until the normal inclined plane from the land to the sea, would be restored.

The next of the properties of Triassic Sandstone to which I wish to direct attention is the *Hygroscopic*, or the power of rapidly absorbing moisture from the atmosphere and giving it off again on any increase of temperature. The method which I have adopted to demonstrate this is the following: 27 months ago I selected a cube of Bunter Sandstone, similar to the one now exhibited, and after dessicating it of moisture, I weighed it, and found the weight to be 14553 grains. This weight was adopted as the zero. On exposing the stone freely to the air it rapidly and steadily absorbed moisture until it was charged to the then state of atmospheric humidity, and from that time to the present, the weight of the stone has varied from day to day and it would vary even from hour to hour, if the humidity should so rapidly change.

I shall now only give two or three illustrations, selected from a great number, which I have on record since the researches were begun. A full account of which would require a paper of considerable length.

In the month of June last year the stone varied in weight *between 38 and* 74 grains. In December it varied between

78 and 107 grains. The least weight, or that which indicated the driest state of the atmosphere since January 1882 was on the 4th June 1883, when the stone contained only 38 grains of moisture, and the most humid state of the atmosphere was on the 26th December 1882 when the stone contained 124 grains of moisture. The account which I am now giving concerning the hygroscopic properties of Triassic Sandstone is doubtless new to you, and I am not aware of any similar previous records having been made bearing upon this question. I shall not at present refer to it in greater detail, for two reasons, namely, the investigations are not yet completed, and it would require more time than is at my disposal this evening to present them even in their state of incompleteness.

Field Meeting, April 14, 1884.

The Annual Easter Field Meeting was held at Llandudno, and conducted by Mr. I. E. George. A visit was first made to Great Ormeshead to note some peculiarities in the weathering of the Limestone rocks; the boulder clays on the shore were also examined. The special feature in the day's work was a visit to the igneous rocks of Bala age which are exposed at Deganway. These belong to the acidic group of igneous rocks, and exhibit not only the ordinary structure of compact felsite, but shew in some places a schistoze structure, while in other places the rock is full of globular concretions.

LIVERPOOL GEOLOGIAL ASSOCIATION.

May 5th, 1884.

At the Ordinary Meeting held this date, at the Free Library, Mr. Henry Bramall, M. Inst., C.E., President, in the Chair, the following were elected Members :—

Rev. S. Gasking, B.A., F.G.S.; Mr. Edmund Dickson, and Mrs. B. Cotter.

Proposed as a Member :—

The Hon. Henry Holbrook, Parkgate, near Chester.

DONATIONS.

"Proceedings," March 1884, Liverpool Astronomical Society; Ditto, Norwich Geological Society, Vol. I. Part 8; Ditto, London Geologists' Association, Vol. 8, No. 5; "Transactions," Vol. I. 1874-83, Burnley Literary and Scientific Club; Ditto, Manchester Geological Society, Part 15, Vol. 17,—*presented by the respective societies*; Paper on "Modern Progress in Mine Engineering" by Henry Bramall, M. Inst., C.E.,—*presented by the Author;* Guide to the Natural History Museum, South Kensington,—*presented by the President*; "Addresses delivered by the Presidents of the Liverpool Philomathic Society, 1828 to 1831,"—*presented by Mr. Elisha Smith, President, Philomathic Society;* "Report of Progress" for 1880-81-82, of the Geological and Natural History Survey of Canada, with seven supplementary Maps,—*presented by Dr. Alfred R. C. Selwyn, F.R.S., Director of the Survey, per the Hon. H. Holbrook.*

MEETINGS FOR PRACTICAL STUDY.

The President stated that the series previously announced, (see p. 34,) of five meetings for Practical Study of Chemical and other tests used in the determination of rocks and minerals, conducted by Mr. A. Norman Tate, F.I.C., had been held on the following respective dates: February 13th and 28th, March 12th and 26th, and April 9th. The following Resolution, proposed by the President and seconded by the Vice-President, was then passed:—"Resolved, that the thanks of the Association be conveyed to Mr. A. Norman Tate for the liberality and kindness which he has shown to the Members of this Association in giving the use of his Laboratory, and conducting the series of Practical Meetings for studying the methods of chemical examination of Rocks and Minerals."

A Paper was read on—

"THE GOLD FIELDS OF BRITISH COLUMBIA,"

By the Hon. Henry Holbrook.

May 17th, 1884.

A Field Meeting was held at the "Red and Yellow Noses," New Brighton, conducted by Mr. P. H. Marrow. The upper beds of the "Upper Mottled Sandstone," which are yellow, are here seen to rest on the lower beds of the same subdivision of the Bunter, which are red. The open cavity of a fault was inspected.

June 7th, 1884.

A Field Meeting was held this date at Northwich. Mr. Thomas Ward conducted the members over the Witton Hall Rock Salt Mine (previously visited by the Association in 1882); to the Salt Works, where the processes in the manufacture of "White Salt" were explained; and to the Marston lake, the scene of the land subsidences. The members were also enabled to inspect the hydraulic lift at Anderton, by which boats are transferred between the Canal and the River Weaver (a difference in level of 50 feet) while floating in a moveable trough, worked by hydraulic pressure.

June 14th, 1884.

A Field Meeting was held this date at Rainhill and Ravenhead. The Rev. H.H. Higgins, M, A, conducted the members through his garden, where several interesting botanical collections were displayed, and to Ravenhead colliery, at which place Coal Measure fossils were obtained.

June 18th, 1884.

An Evening Field Meeting was held at Otterspool, on the banks of the Estuary of the Mersey. The cliff section of Boulder Clay was examined and an interesting description of its contents was given by Mr. C. Potter.

June 28th, 1884.

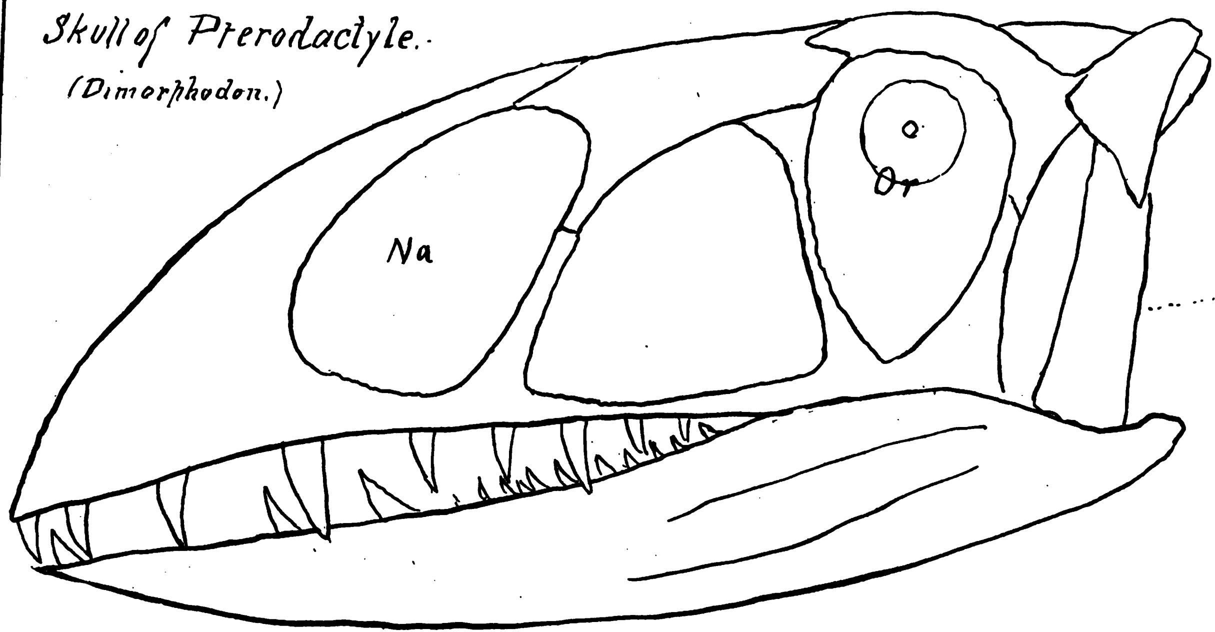
In conjunction with the Liverpool Geological Society, a Field Meeting was held at the Storeton Quarries, Cheshire. Mr. G. H. Morton, F.G.S. conducted the members through the Quarries and explained the geological features of the district, illustrated by his new map on the 25 inch scale. Mr. Morton showed the position of the numerous faults, including the East and West fault in the old quarry, and also the exposure of Keuper Basement Bed in a lane on the West side of the hill.

Pterodactyles.

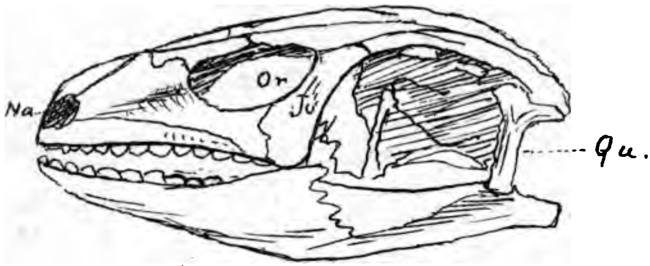
Rhamphorhynchus phyllurus. Marsh. ¼ Nat. Size.

A.W. AUDEN, LITH.

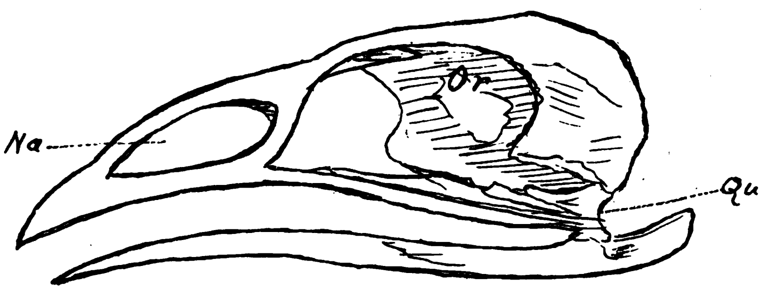
Skull of Pterodactyle.
(Dimorphodon.)



A.W. AUDEN LITH.



Skull of Lizard
(Cyclodus.)



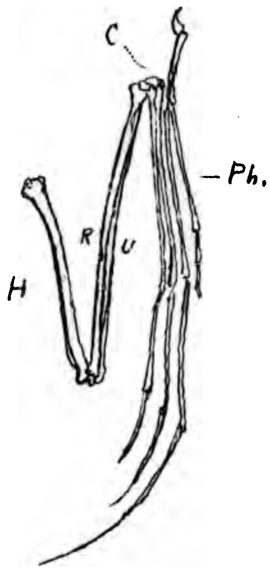
Skull of Turkey.

References.

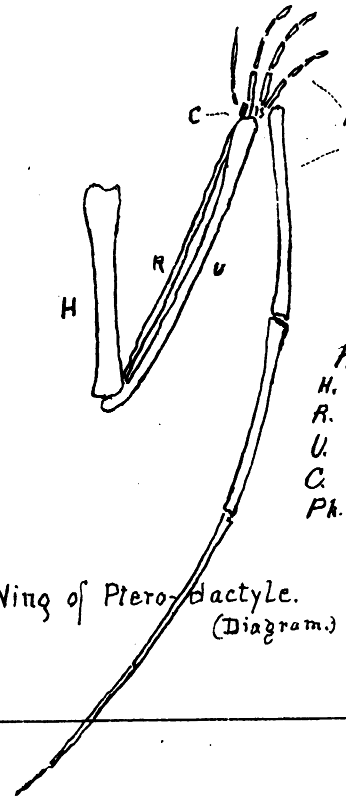
Na. Nasal Fossa.
Or. Orbit.
Qu. Quadrate Bone.

A.W. AUDEN. LITH.

Pterodactyles.

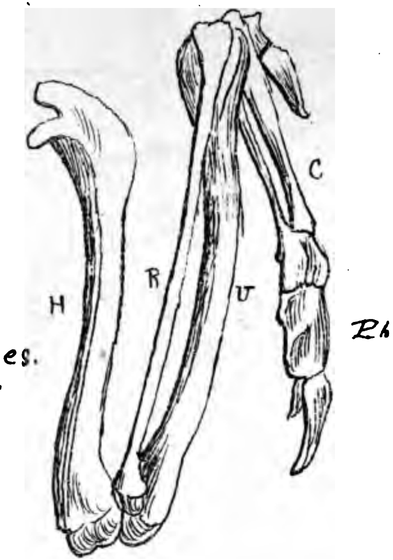


Wing of Bat.



Wing of Ptero-dactyle.
(Diagram.)

References.
H. Humerus.
R. Radius.
U. Ulna.
C. Carpals.
Ph. Fingers.



Wing of Bird.

A.W. Auden. Lith.

LIVERPOOL GEOLOGICAL ASSOCIATION.

July 7th, 1884.

At the Ordinary Meeting held this date at the Free Library, Mr. Henry Bramall, M. Inst., C.E., President, in the Chair, the following member was elected :—

The Hon. Henry Holbrook.

Proposed as Members :—

Messrs. Walter Henry Johnston, 11, Chapel Street, Preston, and George Ernest Gregson, 11, Chapel Street, Preston.

DONATIONS.

Papers by T. Mellard Reade, F.G.S., on—"The Island of South Georgia,"—"Ripple Marks in Drift,"—"Rock-fragments from South of Scotland,"—"A Delta in Miniature,"—*presented by the Author;* Paper on "The Gold Fields of British Columbia," by the Hon. Henry Holbrook, —*presented by the Author;* "Proceedings," London Geologists' Association, No. 6, Vol. 8.; Ditto, Liverpool Astronomical Society, 7th meeting 1883-84 Session, n. d.; with Catalogue of Magnitudes of 500 stars, by T. E. Espin, and "Transactions," No. 2, (various reports); "Reports and Proceedings," Manchester Scientific Students' Association, 1862, 63, 64, 65, 67, 68, 69, 70, 79, 81 and 82,—*presented by the respective Societies;* "Reports," (with accompanying Maps) of the Geological and Natural History Survey of Canada, for 1873, 74, 75, 76, 77, 78, 79 and 80; Memoirs: Canadian Organic Remains, Dec. 1, 2, 3, 4;—Catalogue of Canadian plants, Pt. 1;—Fossil Plants of Devonian and Upper Silurian of Canada, Pt. 1. and 2; Ditto, of Lower Carboniferous;—Palæozoic Fossils, Vol. I, Ditto, Vol. II, Pt. 1; Ditto, Vol. III, Pt. 2;—Mesozoic Fossils, Vol. I, Pt. 1 and 2;—Notes on Geology of Bow River District; On Micro-Palæontology of Cambro-Silurian rocks of Canada;—*presented by Dr. Alfred R. C. Selwyn, F.R.S., Director of the Survey.*

The following Paper was read on—

"PTERODACTYLES,"

BY ANTHONY W. AUDEN.

The Pterodactyle is a Mesozoic form of life, which is now completely extinct, and is an instance of the wonderful method of deduction, examples of which are so abundantly furnished by the Modern Science of Palæontology. The first specimens found were supposed to be bats. Other portions have been set down as those of birds, (as the bones are hollow like those of birds,) but the best authorities are now unanimous in consigning them to the class *Reptilia.*

They have been found in the Lias, Oolite, Purbeck, Wealden and Cretaceous formations, and seemed, till quite recently, most abundant in the Oolite, possibly from their remains being so well preserved in the Oolites of Solenhofen. Recently they have been discovered in great numbers in the Cretaceous Rocks of North America (600 in Yale College alone).

It is also in the Cretaceous where they attain the greatest dimensions. The Oolite forms are small, about the size of a pigeon, but in the Chalk they have attained enormous dimensions much larger than any of the flying birds of modern times. One from the white chalk of Maidstone was sixteen feet six inches from tip to tip of its outstretched wings. And some from the Cretaceous formation of North America are said to have had a spread of wing of from twenty to twenty-five feet, and even thirty feet is spoken of.

To understand the evidence by which the Pterosauria are shewn to be reptiles, it is necessary to note some of the points in the typical vertebrate skeleton, and also to compare the bony structure of our subject, with the skeletons of those members of other classes of animals which are supposed to resemble it.

First, let me point out that in all the forms of animal life possessed of four limbs, the main elements are constant; consisting of a vertebral column composed of bony segments (vertebrae) and divisible into the Cervical, Thoracic, Lumbar and Caudal regions, also a skull and two pairs of limbs. The elements forming the skull and limbs are constant; e. g. in the skull we have the various bones, the frontal, parietal, occipital, &c, in the fore limb we have the scapula, humerus, ulna and radius, carpal, metacarpal and phalanges, and so on in the hind limb.

To take the skull (diagram,) the first thing to strike one is the enormous size of the head in comparison with the body of the animal, on closer examination we note the number of large spaces in it, giving it a framework appearance, and making it light in weight.

In comparing the rough diagrams of the bird's cranium, we see that the orifices or spaces bear the same relation to each

other, but are smaller and in some instances incomplete. The nasal fossa large in the Pterodactyle is much smaller in the bird. The orbit is large in both, but is incomplete in the bird, being confluent with the interspace between it and the nasal opening. The slender columns of bone which divide these spaces in the Pterodactyle, while contributing to the general lightness of the head, give firmness and strength to the dental margin of the upper mandible.

In the occipital region although we find the same elements, still their forms are more reptilian than avine.

In comparison with the skull of the Lizard we find a somewhat closer resemblance, for although the skull, as a whole, is more massive, it not being necessary to economise weight, still the nasal and orbital spaces are completely enclosed by bone, and in the posterior portion of the skull we have a much more reptilian correspondence, the bone which articulates the lower jaw to the upper, called the quadrate is columnar, and has quite the appearance of that in the Lizard. The teeth are crocodilian in form, being conical and set into sockets.

The presence of teeth varied in the different forms which have been found; for instance, the typical form *Pterodactylus* had its jaws toothed to the extremity with equal-sized conical teeth. Its species range from Middle Oolite to the Cretaceous.

The Genus *Dimorphodon* is characterized by having the front teeth long and pointed, whilst the hinder were small and lancet-shaped; this form is Liassic. In *Ramphorynchus*, teeth were present in the hinder portion of both jaws; the front portion was toothless, and probably enclosed in a horny beak; this form is from the Oolite.

The *Pteranodon*, a jurassic genus, had no teeth at all.

The enormous head is supported upon a somewhat long, stout, but flexible neck. The thorax is small, but in some species shews great evidence of rigidity. Prof. Marsh points out that in the Cretaceous *Pteranodon* several of the vertebrae were ancylosed together, as was also the scapula or shoulder blade and the coracoid bones, thus forming a firm attachment for the organ of flight.

The body in general is small but has nothing further remarkable about it. The caudal appendage varied in length, short in the Genus *Pterodactylus*, but long in some other forms.

The most remarkable point in the structure is exhibited in the fore limbs, we have a shoulder girdle composed of a scapula or shoulder blade in some forms birdlike, a coracoid sometimes ancylosed with the scapula, a condition never found in birds, clavicle entirely absent, a bone which is one of the main elements in this portion of a bird's osteology.

A sternum or breast bone with facets for the attachment of sternal ribs, and also having a keel for the attachment of the great pectoral muscles, thus we have a firm and compact fulcrum for the wings made up entirely different from that of a bird, or where we find the same appearance such as the keel on the breast bone, we can point to the same in bats and moles. The fore limb consists of the arm bone (humerus) normal in size, the bones of the fore arm, (ulna and radius,) longer, the wrist bones (carpals,) and the finger bones or phalanges, the latter bones have been variously interpreted by different authorities, but Prof. Marsh the latest, and with the most complete collection of fossils to back him, points out the relation of the various parts at length in an article in "*Nature*," April 6th, 1882, to which I would refer any one who wishes to understand their relation.

The main point in the structure of the arm and hand is the enormous development of one digit, which is in some instances longer than the whole of the body, and which served the purpose of stretching an extenuation of the integument of the body into an organ of flight.

In most of our text books we have an illustration showing the wing finger of one member as the fifth or little finger, and the other as the first or thumb, and this gives us a very fair idea of the state of opinion on the matter, some concluding in favor of it being the one, some the other, and even doing away with one finger entirely, and thus making the fourth or annular finger the wing finger. Prof. Marsh shews that the *wing is stretch*ed by the fifth or little finger, the three small

and free digits being the remaining fingers, and a certain bone (Pteroid,) which is embedded in the flying membrane answering for the thumb, so that we have the whole of the five digits present. Upon comparing this member with that of a bird or bat, we see that there is no correspondence between them. In the wing of a bird the main part is formed of the arm and fore arm the bone of the fore arm being deeply pitted by the attachment of the wing feathers, and the carpus and phalanges are almost indistinguishable and profoundly modified, and all the elements present are concerned in the formation of the wing, while in the bat all the fingers are present and four are elongated and subservient to the organ of flight. In the hind limb there is nothing remarkable, they are small but perfect, have four or five toes, and when the fifth is present it is elongated in correspondence with the fore limb, but not to any great extent, and takes part in the stretching of the membrane of flight.

Thus we have a structure viewed as a whole adapted for flight, a strong fulcrum in the consolidated chest and scapular arch with evidence of powerful muscles, an arm with one finger composed of stout and extremely lengthened joints to which there is every reason to believe a membrane was attached for flying, the membrane extending from the fore part of the arm to the neck, and from the hinder part along the whole length of the body to the outer toe of the hind limb, and thence to the tail, but not to the extremity of that organ. Some have doubted the existence of this membrane, but an unique specimen found in the Lithographic slates of Solenhofern (the same beds which contained the oldest known bird the *Archæopterix*) has traces of this membrane upon it, and shews that the reasoning was correct. This specimen also shews that some if not all of the species had a portion of the tail free, and, not only free, but the terminal vertebrae had the neural and hæmal spines elongated upon which was stretched a membrane, which acted as a rudder to steer its course through the air. It has been supposed by some that these forms of life were able also to move or hop about upon the hinder extremities upon

the earth, perhaps their terrestrial means of progression was on all fours.

The question would now arise what was the place in Nature occupied by Pterodactyles. We have seen they greatly differ from birds, the one organ which is analogous to the wing differs as completely as either birds or Pterosaurians do from bats, complete absence of any trace of feathers, this is negative evidence, but we should reflect that the only specimen of birds found in the same strata as these, had its feathers beautifully preserved; again there is no trace of anything whatever on the membrane of the before-mentioned specimen, and even the bones of the arm bear no trace of the characteristic pitting found in birds, where the base of the great wing feathers have been inserted. To my mind the known existence of birds contemporaneous with Pterodactyles is a sufficient proof of their being in no way the first progenitor of birds. Their affinities with Lizards are strong, and the teeth are essentially reptilian.

The only conclusion to be drawn is that possibly originating in common with birds from the same Lizard-like type, they have taken a different line of development, but being cold blooded and comparatively unprotected from variations of climate, have not been successful in the competition for existence, and like many other forms have lost the battle of life to die out, leaving nothing behind them, but their strange and weird remains to form a subject for the bewilderment of many and to excite the curiosity and reasoning faculty of those lovers of Nature, who try to unravel the fragmentary and imperfect pages of the past, which Geology has laid before us.

July 12th, 1884.

A joint Field Meeting with the Liverpool Science Students' Association, was held this date at Heswall, conducted by Mr. Charles E. Miles. The party visited the remarkable waterworn gullies found in the hillside, running towards the sea shore, the depth of which indicates that the hill has been subject to a considerable amount of denudation, probably chiefly during the Glacial period, or before the deposition of the Boulder Clay. Similar gullies exist in the Red Sandstone in many places now covered by Boulder Clay, and are met with in borings and excavations.

July 17th, 1884.

An Evening Field Meeting was held this date in the Mayer Free Library Grounds, Lower Bebington, conducted by Mr. Charles E. Miles. Several large Glacial boulders were examined, and, by kind permission of Mr. Joseph Mayer, F.S.A., the party afterwards inspected the private gardens and the Museum attached to the Mayer Library.

July 26th, 1884.

A Field Meeting was held this date at Ormskirk, Mr. Isaac Roberts, F.G.S. conducted the members to Greetby Hill, where the base of the Keuper is seen to rest unconformably upon the Upper Bunter Sandstone, and to a section in the St. Helen's Railway cutting, where the Upper Yellow Sandstone is seen resting on the Mottled Sandstone, dipping eastwards under the Boulder Clay.

August 16th, **1884.**

Field Meeting held this date at Prescot, conducted by Dr. C. Ricketts, F.G.S. A quarry in the Pebble-beds, near the Workhouse, was visited, in which occurs a bed of gravel containing pebbles indented and fractured by pressure. In a neighbouring clay-pit, several peculiarly weathered boulders were examined. At the Whiston Colliery a search for Coal Measure fossils was undertaken during the afternoon.

August 30th, 1884.

Field Meeting held this date at New Brighton, conducted by Mr. C. Potter, who described the formation of sand dunes, pointing out several features in which they resemble the deposits of Triassic age in this neighbourhood.

LIVERPOOL GEOLOGICAL ASSOCIATION.

September 1st, 1884.

At the Ordinary Meeting held this date at the Free Library, Mr. Henry Bramall, M. Inst. C.E., President, in the Chair, the following were elected as Members :—

Messrs. Walter Henry Johnston and George Ernest Gregson.

DONATIONS.

"Annual Report." 1883-84, Chester Society of Natural Science;—Ditto, 1883, Yorkshire Philosophical Society ;—"Transactions," Vol. IV, 1883, Liverpool Engineering Society;—"Proceedings," Mining Institute of Cornwall, 1883 ;—Ditto, Liverpool Philomathic Society, 1883-84 ;—Ditto, Liverpool Naturalists' Field Club, 1883-84 ;—"Transactions," Manchester Geological Society, Pts. 16, 17, and 18, Vol. 17 ;—*presented by the respective Societies ;*—"Notes on Boulders in North Hertfordshire" by H. G. Fordham, F.G.S.,—*presented by the Author ;*—"On the Circulation of Water in Sandstone," by T. Mellard Reade, F.G.S.,—*presented by the Author* ;—"The Naturalist," Nos 1 and 2 ;—"Report" of British Association, 1883, (Southport meeting),—*presented by Mr. J. C. Evans ;* Ordnance Survey Map of the Isle of Man, (mounted),—*presented by Mr. Henry Bramall*, (President.

A Reading Stand was presented by Mr. Geo. Robson.

Abstract of a Paper read on—

"THE GEOLOGY OF THE ISLE OF MAN,"

By Daniel Clague.

To the intelligent geologist "every spot is hallowed ground," for wherever he may wander the rocks all speak to him familiarly, and telling him their respective stories give him not a little insight into the state of affairs, which existed in the earlier ages of the world's history. Such are some of the thoughts suggested by the subject before us, for whilst I do not claim for the Isle of Man, that it is more interesting than any other

place, I do assert that it is a "tight little isle" well worthy of our attention, presenting as it does some good illustrations of the simpler lessons in geological study, and also some problems that still await a solution.

The first point to which I shall draw attention is the *alteration in the shore line, which has taken place and is still going on.* A comparison of the old and new maps will make this very clear. The maps issued in 1844 shew that Jurby church was quite a mile from Jurby point, now it is little more than a quarter of a mile from the shore, the sharp angle at Jurby point shewn on the old maps is being rounded off by marine agency; the same force is at work at the Chasms, where an immense mass of rock has broken away from the mainland, subsided several feet, and is split up by many fissures, mainly through the continual battering of the sea at its base. Another illustration of the force of marine denudation is found at Hango hill, where the remains of an old building stand on the edge of a cliff 20 to 30 feet high, the greater part of both cliff and building having been swept away, only two detached blocks of masonry now remaining to shew where the building stood.

Elsewhere the sea is engaged in other work, *building up and adding to the land,* this is very noticeable on the North Coast; the lighthouse on the Point of Ayre was in 1818 on a shoal on the coast, it *is now inland.* Mr. Henslow supposes that the land encroaches on the sea there at the rate of one yard per year, this addition to the land is caused by the shingle and sand carried by currents, being deposited on the shore and cemented together by carbonate of lime.

The Physical Structure of the Island may be briefly described, as a scalene triangle of clay schist with its most acute angle at the Calf, and its shorter edge stretching from Ballaugh to Maughold rising in the North to an altitude of 2000 feet, which steadily decreases to 300 feet at the Calf; the triangle of schist is flanked at Peel by Sandstone Cliffs, at Castletown by Carboniferous Limestone, and on the North beyond Sulby, by a second triangle of Marls, sands and gravel. It is intersected by two valleys, which were filled at

one time by the sea, so dividing the present Island into a group of at least four islands.

STRATIGRAPHICAL GEOLOGY OF THE ISLAND.

The oldest formation is that composed of clay schist, it forms an anticlinal, the axis of which is roughly N. E. by S. W., this anticlinal however is somewhat broken, as in many places the "rocks mantle round a series of bosses" (Cumming) formed by the upthrusting of igneous matter.

There is considerable diversity of opinion as to the age of these schists, some eminent geologists classing them with the Cambrian, and others equally eminent call them Silurian, as the only means of settling the question is not to hand, I fear it must remain open, until some student of Manx rocks, discovers fossils by which to determine their age.

Very few fossils have yet been discovered, and those are of a very doubtful character. Several writers speak of fossil plants having been found to which they give a variety of names but from a comparision of their descriptions, it is clear that they all speak of the Palæochorda, which though once regarded as plant remains are now generally attributed to the action of water, that being the same in all ages cannot fix the age of any rock in which they may be found: other markings supposed to be foot-prints have been found occasionally, they are described as being of an oval form 9 inches long, 6 inches wide, and two inches deep, and have been called Protichnites, that is imprint of the legs and feet of Trilobites, or some such like crustacean, if so they must have been of enormous size, far exceeding the largest Paradoxides known; but the description given of them, reminds one much more of the Raschinites or Trilobite burrows, figured by Dawson, last year I found a number of impressions at Port Soderick similar in character to these but much smaller, they not exceeding three quarters of an inch in length. There is evidently room for much research in this direction, and I am not without hope that bye and bye some of our members will succeed, by discovering undoubted fossils, in deciding the age of these schists.

*The abun*dance of ripple marks and rain pittings, testify

that some of these schists at least were laid down as mud in shallow water, and were occasionally left dry, and slowly subsiding left a series of ripple marks in a great thickness of rock, which seen in section might be mistaken for contortion. Subsequently this mud deposit was subjected to those forces, which have thrown so much of our country into anticlinals and synclinals, next the anticlinals were denuded so that the overlying formation rests on the upturned edges of the schists.

The next rock in ascending order is *Sandstone*, generally regarded as "*Old Red*", it is exposed near Peel. Certain conglomerates in the South of the Island are classed by Cummings with this Sandstone as of the same age, but a close study of them tends to shew that they belong to different ages, and were laid down under different conditions. Much work needs to be done in this department also.

The *Carboniferous Limestone* comes next, it is divided into upper and lower, both of which abound with characteristic fossils, the lower beds attaining a thickness of 160 feet of dark colored stone, the upper beds are chiefly light colored with the exception of the Posidonia schist, or Poolvash Marble as Manxmen love to call it, which is very dark, nearly black. During the deposition of the Upper Limestone, volcanic forces were at work resulting in the formation of a number of dykes of trap rock, and the emission of volcanic matter, which are seen at Longness, Scarlet and Poolvash, at the latter place is an interesting bed of calcareous ash containing fossils, which fix the geological era of the outburst; at Scarlet is a mass of basalt which probably consolidated in the neck of a volcano.

After the deposition of the limestone a great geological gap occurs, for the next beds in succession are of Pleistocene age, the Glacial drift being well represented telling of alternate subsidence and elevation of the land; during the elevation period the Isle of Man was probably connected with the rest of Great Britain, and the huge Irish Elk (Cervus Megaceros) roamed over the elevated bed of the Irish Sea; when the subsidence ensued a few of the Elks were imprisoned on the Islanp and dying there, left their bones in the Marl beds along with

stone implements of human manufacture.

The schists and limestone of the Island afford excellent building material; the limestone and the Marls are used by agriculturalists, but the chief *mineral wealth* of the Island, consists of Lead, Copper and Zinc ores, which are worked at Laxey, Foxdale, and Ballacorkish, Galena the principal lead ore is rich in silver, besides these, Iron Wolfram and Fahlerz have been found, and of late years, the rare mineral Plumosite has been found at Foxdale.

If in this paper I have brought out no new facts, and broached no new theories to astonish the Geological world, I hope I have been able to bring forward such facts as will stimulate our members to study the Geology of the Island, when they visit it for a very different purpose.

The Paper was illustrated by diagrams, maps and specimens, from the collection of the Author, and by others kindly lent for the occasion, by Messrs. A. Quilliam, Clarke, Dudley, and Capt. Kitto.

END OF VOLUME IV.